Revision ______________

Date ______________

BWR SYSTEMS

LESSON PLAN

A. LOCAL POWER RANGE MONITOR (LPRM) SYSTEM

B. REFERENCES

1. BWR Systems Manual - Chapter 5.3
2. GEK 32551 - Power Range Monitoring System - Brown's Ferry
3. GEK 32552A - Power Range Neutron Monitoring System Components Brown's Ferry
4. NEDO - 10806 - Reactor Fundamentals Training Manual - Volume 6.
5. GEI - 92823B - Nuclear Engineer's Manual
6. Final Safety Analysis Report - Brown's Ferry Nuclear Plant
7. Brown's Ferry Procedures
    a. Operating Instruction O.I. 92
    b. Tecnnical Instruction T.I. #4, #5, #11
8. Cord File - 5.3

C. OBJECTIVES

1. To understand power in core, neutron monitoring instruments (LPRMs)
2. To understand indicators, alarms and interlocks originating in the LPRM subsystem.
3. To understand administrative and related LPRM Technical Specifications.

D. BRIEF DESCRIPTION

1. Purpose
    a. Subsystem of power range monitoring system which consists of:
        1) Local Power Range Monitors (LPRMs)
        2) Average Power Range Monitors (APRMs)

3) Rod Block Monitors (RBMs)

b. Continuously monitor local thermal neutron flux

c. Alarm on excessive flux condition

d. Assist in the evaluation of local heat flux conditions and calculation of Minimum Critical Power Ratio (MCPR)

e. Provide local power indication inputs to the APRM and RBM subsystems and Process Computer.

2. General Description (Figure 1)

a. Detector

1) <u>Purpose</u> - Detects local thermal neutron flux and converts it to an equivalent analog current signal.

2) 172 detectors in core

b. Detector Assembly (LPRM String)

1) Houses 4 Local Power Range Monitor (LPRM) detectors, detector cables and calibration dry tube for Traversing In-core-Probe (TIP) detector.

2) 43 assemblies in core

c. Power Supplies

1) Purpose

a) Provide detector bias

b) Provide amplifier, indication and trip unit power

2) Located in Power Range Monitoring System cabinets in the control room panel 9-14.

d. Flux Amplifier

1) <u>Purpose</u> - Converts detector current signal to an analog voltage signal.

2) One amplifier per LPRM detector, 172 total

3) Located in Panel 9-14.

e. Trip Units

1) Purpose - Provide alarm signals upon abnormal conditions

2) Located in Panel 9-14.

E. COMPONENT DESCRIPTION

1. Detector (Figure 1)

a. Fission Chamber

1) Similar to SRM and IRM with minor differences

2) 2.0" long (sensitive length) x .23 in diameter.

3) $U_3^{235}O_8$ (90% enriched) electroplated to outer electrode (case), approximately 1 milligram of U^{235} per detector.

4) Argon filled to 1.3 atmosphere (91.5 cm Hg., 19.1 psia)

5) Ionization Chamber

b. Operating Specifications

1) Operating bias (DC voltage across electrodes) 75 - 200V DC normally set at looV DC.

2) Neutron sensitivity 1.0×10^{-17} ampere/NV at beginning of life decreasing approximately 10% per 300 MWd/t average core exposure due to uranium detection.

3) Gamma sensitivity 2.0×10^{-14} amperes/R/hr. - Doesn't change with life, as it is not affected by uranium depletion, but is a function of argon pressure. which does not change with life.

4) Beginning of life sensitivity

a) Maximum neutron flux in core $\sim 1.3 \times 10^{14}$ NV so:
1.0×10^{-17} ampere/NV x 1.3×10^{14} NV = 1.3×10^{-3} ampere

b) Hence maximum expected detector current from neutrons = 1300 microamps.

c) Maximum γ flux in core 6.5×10^{8} R/hr. so:
2.0×10^{-14} amp/R/hr. x 6.5×10^{8} R/hr. = 13×10^{-6} amp

d) Hence maximum expected detector current from gammas = 13 microamps.

e) Beginning of life neutron to gamma signal ratio 100:1.

5) End of life sensitivity

a) Minimum usable full scale detector current is 75 microamperes.

b) Gamma current, being a function of argon gas pressure, doesn't change with life, so remains at 13 microamperes.

c) End of life neutron current is then 75-13 or 62 microamperes.

d) End of life neutron to gamma signal ratio ~5:1.

e) End of detector life criteria are based on current output and neutron to gamma signal ratio.

(1) Current drops too low, gain cannot compensate

(2) If gamma is too high, response is not good to changes in power, since a*

6) Detector assemblies in high flux areas must br replaced at approximately 3 year intervals. (~3.78 x 10^{21} NVT)

2. Detector Assembly

a. Locations

1) Narrow-narrow gaps (Figure 2)

NOTE: Spacings (water gaps) between fuel bundles are not all the same.

a) The gaps which the control rods fit into are wider than the gap caused by the top guide.

b) The center of the control rods are at the intersection of the wide gaps (called the wide-wide water gap).

c) The neutron instrumentation is at the intersection of the narrow gaps (hence narrow-narrow gap).

d) Nothing is located in the wide-narrow gaps.

2) Core Symmetry (Figure 3)

a) Symmetry discussed is both mirror and rotational.

b) Rods symmetrically located in core.

*Significant portion (40%) of the gamma flux at steady state is from fission product decay and is thus delayed.

c) Rod patterns are symmetrical.

d) Therefore flux patterns are symmetrical.

e) LPRM assembly locations are not symmetrical.

f) Instead, assemblies are positioned so that every location or its symmetrical counterpart in another quadrant is monitored.

g) This symmetry is shown by phantom symbols in upper right quadrant of Figure 3.

3) Axial Location (Figure 4)

a) Located to give best estimate of axial flux profile.

b)

Level Designation	Location Above Bottom of Active Fuel
D	126"
C	90"
B	54"
A	18"

c) Assemblies are fixed in core and do not retract like SRM and IRM detectors.

b. Mechanical Description of Detector Assembly (Figure 5)

1) 304SS tube, approximately 42 feet overall length.

2) Installed into in-core guide tube from above

3) Top is spring loaded into recess in top guide.

4) Bottom end sealed into thimble with three seals.

a) Thimble sealed to flange with "O" ring.

b) Detector sealed metal to metal into mating surface in thimble.

c) Moisture sealed out of connection sleeve with teflon seal compressed by nut.

5) Wet tube, i.e. holes drilled-several for detector cooling.

6) Detector connections inside sleeve.

7) TIP tube connected with flare fitting at bottom.

c. Cross Section (Figure 6)

1) 0.700" O.D., 0.640" I.D. (.030" wall thickness)

2) Contains

a) 4 LPRM detectors

b) Detector cables

c) Dry tube for TIP detector transit

3. Power Range Neutron System Cabinets (Figure 7)

a. Purpose - Contain all circuitry associated with the Power Range Neutron Monitoring System

b. Location - In control room, Panel 9-14.

c. Hold LPRM bias supplies and amplifier cards

d. Hold APRM Channels A-F, LPRM Channels A+B, RBM Channel A+B equipment.

e. 5 Standard Equipment Racks

1) Each rack holds 2 Channels i.e.

a) 2 APRM channels, or

b) 1 APRM channel and 1 LPRM group, or

c) 2 RBM channels

2) Each channel made up of two card racks called pages (Figure 8)

NOTE: Printed circuit card rack called a page since front page swings out like a page of a book.

a) Front page contains LPRM amplifier cards.

b) Rear page contains detector bias supplies.

c) Meter on front page extends through cabinet door.

3) Number of LPRM amplifier cards in APRM channels or LPRM groups:

Channel	Number
APRM Channel A	21
APRM Channel C	21
APRM Channel E	21
APRM Channel B	22
APRM Channel D	22
APRM Channel F	22
LPRM Channel A	21
LPRM Channel B	22
	172 total cards

4) The 172 amplifier cards correspond to 172 detectors in core.

5) No LPRMs are assigned to the Rod Block Monitors and hence no LPRM cards are contained in the RBM pages. The RBMs selectively use outputs from all LPRMs assigned to APRM channels and LPRM Channels.

4. Power Supplies

a. Sources

1) All power for LPRM circuitry is supplied from the APRM or LPRM channel to which it is assigned.

2) There is one bias (high voltage) supply for each LPRM (each detector). All other DC power supplies are common to all LPRMs assigned to an APRM or LPRM group.

3) The bias supplies get power from the page into which they are inserted.

b. Bias Supply

1) Supplies high voltage to detector

2) Variable 75 - 200V DC (normally set at 100 volts), at a maximum load of 3 ma.

5. Amplifier Printed Circuit Card (Figure 1)

a. Purpose

1) To convert small detector output into signal large enough to drive trip units and indication downstream.

2) Converts detector current output signal to analog voltage signal of 0 - 10 volts DC which normally corresponds to fuel cladding surface heat flux of 0 - 125 watts/cm^2.

b. Ranges

1) Amplifier has 3 ranges to accomodate depletion of uranium in detector over its lifetime.

Range	Input Current for 10 Volts Out	When Used
Lo Gain	800 - 3000μA	Beginning of life
Med Gain	200 - 1000μA	Middle of life
Hi Gain	50 - 250μA	End of life

2) Selected with range switch using a screwdriver.

3) Adjustment over range made with gain adjustment potentiometers (also by screwdriver)

c. Function Switch S-1

1) Location - Front, top edge of amplifier

2) Purpose - To allow for calibration of LPRM amplifier and for bypassing inoperative LPRM.

3) Three positions

a) O (Operate)

b) C (Calibrate)

c) BY (Bypass)

4) Three decks (section) S1A, S1B, S1C

a) All decks operate together when thumbwheel is turned.

b) S1A on output of flux amplifier.

c) S1B switch - 15V to various control logic.

d) S1C on input to flux amplifier.

5) Operate Position

a) SLA - Connects flux amplifier to averaging circuit, RBM select matrix and process computer.

b) SIB - Connects -15V to count circuit through resistor giving current signal to count amplifier (count circuit part of APRM system) and -15V to averaging circuit (part of APRM system)

c) SIC - Connects detector current from power supply to flux amplifier.

6) Calibrate Position

a) SLA - Disconnects output of flux amplifier from averaging circuit, RBM select matric and process computer.

b) SIB - Sends -15 volts to calibrator, interrupts -15 volts to count and averaging circuits.

c) SIC - Connects output of calibrator to input of flux amplifier.

d) Output of flux amplifier can now be read on panel meter during calibration without effecting computer, APRM or RBM indications.

7) Bypass Position

a) SLA - Same as calibrate position.

b) SIB - Sends -15 volts to trip inhibit circuit which inhibits upscale and downscale trips and generates bypass signal.

c) SIC - Same as Calibrate.

d. Outputs from Flux Amplifier

1) APRM Averaging Circuits

a) LPRMs assigned to LPRM channels A + B do not go to an averaging circuit. The LPRM channel pages furnish power, but no average output is produced.

b) This arrangement is because only six APRMs are necessary, and the LPRM channels house those LPRMs not used by APRMs.

2) Process computer for use with traversing In-core Probe System to establish core flux shape.

3) Rod Block Monitor System

   a) Signals all go to a relay selection matrix (discussed later under Rod Block Monitor System).

   b) Isolated by buffer amplifier to keep select relay noise from being backfed to the APRM input from the select matrix.

4) Panel Meter Selection Switches

   Individual LPRM outputs can be displayed on meter. (Discussed further under APRM presentation)

5) Upscale and Downscale Trip Units

e. Trip Units

1) Located on Amplifier Card

2) Operate by Comparing Reference with Input Signal.

3) Two types

   a) Upscale trip

   b) Downscale trip

4) Upscale trip unit trips when input rises above reference (~100 watts/cm^2 *

5) Downscale trip unit trips when input falls below reference (3 watts/cm^2).

6) Both trip units have two types of outputs.

   a) Seal-in (must be manually reset)

   b) Auto Reset (Reset as soon as input returns to normal range.)

* Actual LPRM upscale trip settings are different for each LPRM, and are based on the maximum allowable heat flux on any rod segment in the local area of the detector. (See SFMP - [illegible])

7) Seal-in outputs drive local indicator lights located at or Panel 9-14.

8) Auto reset outputs drive lights on full core display (Panel 9-5).

F. INSTRUMENTATION

1. Panel 9-5.

a. Full Core Display (Figure 9)

1) 2 alarm lights for each LPRM detector

a) Amber light (Hi)
Upscale trip 100/125 of scale

b) White light (Lo)

Downscale trip 3/125 of scale.

2) Botn are auto reset.

b. Four Rod Display (Figure 10)

1) 16 LPRM Output Meters

a) Purpose - To display the four LPRM string outputs around the selected rod, showing local fuel cladding surface heat flux indications.

b) Input LPRMs are selected by Rod Block Monitor System selection matrix.

c) Calibrated in watts/cm^2 (fuel cladding surface heat flux), not % power.

2) 16 White "LPRM Bypassed" lights Beside Meters

a) Illuminated whenever LPRM output to RBM is bypassed

b) Bypass conditions discussed in detail under RBM System.

2. Panel 9-14

a. Top Section (Figure 11)

1) 3 lights per LPRM

a) Left Light

(1) White light

(2) Illuminated when function switch on LPRM card in bypass.

b) Center Light

(1) White light

(2) Downscale trip indicator - seal-in (setpoint 3/125)

c) Right Light

(1) Amber light

(2) Upscale trip indicator - seal-in (setpoint 100/125)

2) Label Under Lights

a) Indentifies LPRM 2 Ways

(1) Core location

(2) Meter selection switch position

b) First number indicates LPRM Selector Switch (described later under panel meter) position for the LPRM.

c) Letter indicates 2 Things

(1) Meter function switch position

(2) Axial level in core.

d) Last 4 numbers (xx-xx) indicate LPRM string position in core.

3) Other lights (associated with LPRM) atop 9-14 will be discussed under APRM System.

b. Meter Section (Figure 12)

1) Three different meters are used.

a) One for APRMs

b) One for LPRM groups.

c) One for Rod Block Monitor

2) The one shown here is an APRM meter. All three will be discussed in detail later under APRM and Rod Block Monitor Systems.

3) Meter Input Selection

a) The meter is usually left to read APRM output, but can be selected to read the output from any LPRM assigned to that APRM.

b) To read individual LPRM output:

(1) Set function switch to level (axial core height) that LPRM of interest is located at (A, B, C or D)

(2) Set LPRM selector switch to number corresponding to first number in label under associated alarm lights on top of Panel 9-14 (numbers go from 1 to 6).

c) The meter will read level clad surface heat flux in watts/cm^2 on the 0 - 125% scale.

4) LPRM Bypassed Light (Figure 12)

a) Indicates LPRM selected with function switches and displayed on meter is bypassed.

5) Meter Expand Light

a) Indicates meter is 10 x more sensitive than the dial calibration indicates (caused by switch in APRM).

6) Trip Reset Pushbutton

a) Resets all seal-in trips on top of panel associated with that APRM or LPRM group.

c. LPRM Amplifier Card (Figure 1)

1) Function "Thumbwheel" Switch

a) Three Positions

(1) OP (Operate)

(2) C (Calibrate,

(3) By (Bypass)

b) Allows LPRM to be removed from APRM input for calibration or if it has failed.

2) Gain Switch

a) Three Positions

(1) Hi

(2) Med

(3) Lo

b) Allows change of gain adjustment range to compensate for depletion of U^{235} in detector.

3) Gain Adjustment Potentiometers

a) One per range of gain

b) Adjust gain or flux amplifier to compensate for burnup.

c) Allows calibration of individual LPRM's.

G. RELATIONSHIPS TO OTHER SYSTEMS

1. Power Supplies

a) All power supplied from related APRM or LPRM group.

2. System Outputs (Figure 1)

a. RBM

b. APRM (if assigned to APRM)

c. Process Computer

d. Back Panel 9-14 Meter

e. Trip Indication to Full Core Display and Top of Panel 9-14.

3. System Inputs

a. Individual LPRM's are powered from associated APRM or LPRM Channel.

b. Calibration current from APRM or LPRM Channel (Discussed under that presentation).

4. Mechanical Interface

   a. TIP uses dry tube in detector assembly when traversing core.

H. TECHNICAL SPECIFICATIONS

1. There are no technical specifications that apply to the LPRMs except as they apply to the APRMs and RBM. (APRM and RBM covered in a separate lesson.)

Revision ________________

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BWR SYSTEMS

LESSON PLAN

A. AVERAGE POWER RANGE MONITOR (APRM) SYSTEM

B. REFERENCE

1. BWR Systems Manual - Chapter 5.4.
2. GEK - 32551 - Power Range Monitoring System - Brown's Ferry.
3. GEK - 32552A - Power Range Monitoring System Components - Brown's Ferry.
4. GEK - 13956B - APRM Flow and Auxiliary Unit
5. Final Safety Analysis Report - Brown's Ferry Nuclear Plant.
6. GEK - 32556 - Reactor Protection System - Brown's Ferry
7. Brown's Ferry Procedures
   a. Operating Instructions - OI 92
   b. Surveillance Instructions - 4.1.B-1, 4.1.B-2, 4.1.B-15.
   c. Technical Instructions TI 6.
8. Brown's Ferry Technical Specifications.
9. Card File 5.4.

C. OBJECTIVES

1. Gain a functional understanding of APRM System design and operation.
2. Understand all APRM alarms, trips and interlocks.
3. Understand administrative and Technical Specification requirements associated with the APRM System.

D. GENERAL DESCRIPTION

1. The APRM System is a subsystem of the Power Range Monitoring System.
2. Design Basis

a. The design of the APRMs shall be such that for the worst permitted input LPRM bypass conditions, the APRMS shall be capable of generating a scram trip signal in response to average neutron flux increases resulting from abnormal operational transients in time to prevent fuel damage.

b. The design of the APRMS shall be consistent with the requirements of the safety design basis of the Reactor Protection System.

c. The APRMS shall provide a continuous indication of average reactor power from a few percent to 125% of rated reactor power.

d. The APRMS shall be capable of providing trip signals for blocking rod withdrawal when the average reactor power exceeds pre-established limits set to prevent scram actuation.

e. The APRMS shall provide a reference power level for use in the Rod Block Monitor Subsystem.

3. System Description

a. APRM System receives inputs from:

1) LPRM System

2) Recirculation System flow elements

b. The APRM System generates

1) Indications of core bulk thermal power.

2) Signal proportional to total recirculation loop flow.

3) Flow biased rod blocks and scram trips (with mode switch in Run)

NOTE: Flow biased means trip setpoints are a function of recirculation flow.

4) Constant power rod blocks and scram trips (with mode switch in Startup and Refuel.)

5) Downscale and inoperative (Inop) trips.

c. The APRM System sends these signals to:

1) Recorders on Panel 9.5

2) Meters on Back Panel 9-14.

3) Process Computer

4) Rod Block Monitor System (reference APRM input)

5) Reactor Manual Control System (Rod Blocks)

6) Reactor Protection System (Scram trips)

d. APRM System consists of 6 APRM channels (A + F) (Figure 1)

e. Basic Components (Figure 2)

1) Averaging circuit - averages assigned LPRM inputs to give output signal proportional to core bulk thermal power.

2) Count circuit - Produces output proportional to number of assigned LPRMs active (not bypassed with thumbwheel switch).

3) Flow converter - Produces output signal proportional to recirculation loop flow.

4) Trip units

a) Compare average core power signal with recirc loop flow signal to give flow biased trips in Run mode.

b) Give constant power trips in Startup mode.

5) Calibrator - Produces calibration current for calibrating assigned LPRMs.

6) Indication

a) Recorders shared with IRMs on Panel 9-5.

b) Meters on panel 9-14.

E. COMPONENT DESCRIPTION

1. LPRM assignments to APRM Channels and LPRM Channel.

a.

Number LPRMs Assigned	Channel
21	APRM Channel A, C and E
21	LPRM Channel A
22	APRM Channel B, D and F
22	LPRM Channel B

b. Methods of Assignment (Figures 3 and 4)

1) Orderly pattern across core.

2) Selected so every APRM will give good core average power signal.

3) Assignments are symmetric on diagonals through LPRM string at core location 32-33.

4) APRM Channels A, C and E and LPRM Channel A on one set of diagonals.

APRM Channels B, D and F and LPRM Channel B on the alternate set of diagonals.

5) Each LPRM detector assigned to only one APRM or LPRM Channel and substitution between APRMs and LPRM Channels cannot be made.

c. Reason for LPRM Channels

1) 172 detectors need to properly monitor local flux patterns in core.

2) Approximately 20 LPRMs needed for each APRM Channel.

3) Only six APRM Channels needed:

a) 4 needed for 1 out of 2 twice logic.

b) Other two needed so that one APRM in either RPS Channel A or B can be bypassed for maintenance during normal operation.

c) Extra LPRMs needed for local core monitoring but not needed for APRM inputs are assigned to LPRM Channels.

4) LPRM Groups are assigned to APRM System since they also receive power from RPS Buses.

2. Averaging Circuit (Figure 2)

a. Purpose

1) To produce a signal equal to the average of all LPRM inputs to the circuit.

2) This signal, which is a core average neutron flux signal, is calibrated so that 0 - 10 volts corresponds to 0 - 125% of rated core thermal power (3293 MWt).

b. Operation

1) Each LPRM signal has its own input and feedback resistor.

2) These resistors are connected to the averaging amplifier by a relay which is picked up when the LPRM "thumbwheel" function switch is placed in Operate.

3) The additional feedback resistor added when an LPRM is placed in Operate decreases the amplifier's gain just enough to offset the increase in output caused by the additional input signal.

4) This keeps the output signal equal to the average of those LPRM inputs feeding the averaging amplifier, regardless of how many LPRMs are bypassed.

3. Count Circuit

a. <u>Purpose</u> - To generate a signal which is used to:

1) Indicate the number of LPRMs assigned to an APRM Channel that are in Operate.

2) Generate an Inop trip if the number of LPRMs in Operate is too low.

a) This trip is required to insure that the APRM gets a representative sampling of flux across core.

b) At least 14 of the LPRMs assigned to an APRM must be in Operate.

b. Operation

1) Each LPRM sends the count circuit a fixed current signal when its function switch is in Operate.

2) Count amplifier changes current inputs to voltage output.

3) Feedback resistor sets gain of amplifier so that each current input will yield 5% on meter scale which goes from 0 to 125% (meter circuit described later).

4. Flow Converters and Flow Arithmetic Units

a. <u>Purpose</u> - To provide flow signal for use in setting flow biased rod block and scram trip functions.

b. Operation

1) Flow Arithmetic Unit

a) Gets 10 - 50 ma signals from flow elements in both recirculation loops.

b) Takes the square root of each signal, developing at 10 - 50 ma signal linearly representing 0 -125% flow.

c) Sums signals, so that both arithmetic flow units develope total recirculation loop flow, which is the sum of A and B loop flows.

2) Flow Converter Unit

a) Converts this signal into 0 - 10 volt signal which corresponds to 0 - 125% flow.

b) Outputs of converters are compared as a check on proper operation.

c) If either varies from the other by 10% it will generate a trip causing a flow converter Inop Rod Block.

d) If either converter output reaches 110% it will also generate a trip causing a flow converter Inop Rod Block.

c. Arrangement

1) Only two flow converters total, both shown on Figure 2.

2) Flow converters Unit A feeds:

a) APRM Channels A, C and E

b) Rod Block Monitor (RBM) Channel A

3) Flow converters Unit B feeds:

a) APRM Channels B, D and F.

b) RBM Channel B

4) Flow converters are located in bottom of APRM cabinets. (See Figure 1)

E. Trip Units

a) Purpose

1) To provide scram signals to the Reactor Protective System or Rod Withdrawal Block signals to the Reactor Manual Control System when a measured parameter exceeds (or drops below for downscale trips) a preset level.

2) To provide Inop trips upon detection of malfunction internal to system circuitry.

b. Operation

1) Input sigaṇl is compared to reference signal.

a) On upscale trip, unit will trip when input exceeds reference.

b) On downscale trip, unit will trip when input falls below reference.

2) Each trip unit has two outputs.

a) Seal in

(1) Output stays tripped until reset by pushbutton on local panel.

(2) Drives local alarm lights.

b) Auto Reset

(1) Output resets as soon as trip condition clears.

(2) Drives alarms on Panel.

(3) Feeds Reactor Manual Control System or Reactor Protection System.

6. Slope and Bias Circuit (Figure 2)

a. Purpose - Provides flow biased reference for APRM Hi and Hi-Hi trips.

b. Operation (Figure 5)

1) Converts flow signal from flow converter into reference function as shown on Figure 5.

2) With no flow, scram reference (Hi-Hi reference) is 54%. Rod Block reference (Hi reference) is 42%.

3) Both reference functions rise linearly with flow until flow signal reaches 100%, when scram line reaches 120% and Rod Block line reaches 108%.

4) Hence, both lines rise 66% while flow rises 100%, so slope is .66% x recirculation flow (W).

5) The flow biased scram signals limited to this value and cannot go above 120%.

7. Mode Switch Contacts (Figure 2)

a. Purpose

1) The mode switch modifies trips and interlocks consistant with the mode of reactor operation (Run, Startup, Refuel, Shutdown).

2) The safety limit for core thermal power below 800 psia or less than 10% of rated core flow is 823 MWt (~25% rated thermal power).

3) Reactor will scram if mode switch placed in Run with reactor pressure less than 850 psig due to MSIV closure and resultant scram.

4) Scram trip reference is fixed at 15% when the mode switch is in other than the Run position where the reactor can be less than 800 psia.

5) Thus, the mode switch interlock here assures that reactor power will not exceed 15% when reactor pressure is below 800 psia.

b. Operation

1) With the mode switch contacts open (mode switch in Startup, Refuel or Shutdown) fixed reference signals (12% Rod Block, 15% scram) are generated by resistive voltage dividers and fed to the respective trip units.

2) With mode switch contacts closed (mode switch in Run), the flow biased reference overwhelm the voltage dividers and the fixed reference have no effect on trip setpoint, even though they are still connected.

8. Calibrator (One per APRM Channel or LPRM Channel, 8 Total) (Figure 3)

a. Purpose - Provides a calibrated current signal for use in calibrating LPRM flux amplifiers to compensate for detector depletion due to Uranium burnup.

b. Operation

1) Operates on the theory that fixed voltage across a fixed resistor will produce a fixed current signal.

2) Generates a carefully regulated 10 volt signal.

3) 10 volts fed to a precision resistor assembly controlled by thumbwheel switches. Read on meter by depressing "Monitor" Switch (Figure 9), adjusted by "Adjust" Control.

4) Current output from this assembly is variable from 1 to 3999 microamperes (μA or $10^{-6}A$) in steps of 1 μA.

5) Current output μA is equal to number dialed into thumbwheel switches.

6) Output current directed to proper flux amplifier by selection switches discussed later under controls.

7) Calibration of LPRM's will be discussed under Traversing In-Core Probe (TIP) System.

9. APRM Calibration Devices (Figure 9)

a. Power test - with APRM operate switch in Power Test.

1) All flux amplifier inputs are removed from the averaging amplifier.

2) "Power" adjust is substituted for averaging amplifier input.

b. Flow Test - In "PWR Flow" Test position

1) Action as described above for "Power" test.

2) "Flow" adjust is substituted for recirculation flow into the slope and bias circuits.

10. Power Supplies

a. Sources

1) Reactor Protection System (RPS) Bus A supplies 120V AC to:

a) APRM Channels A, C and E

b) LPRM Channel A

c) Flow converter Unit A

d) This includes all local indications and LPRM Hi and Lo lights on full core display.

2) RPS Bus B supplies 120V AC to:

a) APRM Channels B, D and F

b) LPRM Channel B

c) Flow converter Unit B

d) This includes all local indications and LPRM Hi and Lo lights on full core display.

3) Instrument bus supplies:

a) Hi-Hi, Hi, Downscale and Bypass lights on apron section of 9-5.

4) Uninterruptible Power supplies recorder power.

b. Distribution

1) Internal power supplies located in Power Range Monitoring cabinets transform and rectify 120V AC RPS bus voltage into suitable voltages for logic and indicator lights.

2) Each APRM Channel, LPRM Channel and flow converters has its own power supplies.

3) The APRM or LPRM Channel supplies furnishes power to the associated LPRM circuit cards and detector bias supplies.

F. INSTRUMENTATION

1. Control Room Instrumentation (Panel 902-5)

Item	Device	Range
Core thermal power	Recorder (6) (shared with IRM)	0 - 125% rated thermal power (3293 MWt)

2. Significant Alarms, Interlocks and Trips

a. Control Room Annunciators (Panel 9-5)

Annunciator	Setpoint	Function/Remarks
APRM HIGH	.66W + 42% (Run mode 12% (other than Run mode)	Rod Block
APRM DOWNSCALE	3% of scale	Rod Block (Run Mode) scram with companion IRM Hi Hi (any other Mode)
APRM FLOW BIAS OFF NORMAL	10% mismatch or 110% either channel	Rod Block
APRM HI HI OR INOP	.66 + 54% (Run mode)* 15% (other than Run mode)*	Scram

*Inop Trips Listed Inder Trips and Interlocks Below.

b. Alarms Other than Annunciators

1) All alarms on Panel 9-5 are auto reset; all local alarms are seal in and must be manually reset locally.

2) Setpoints for alarms will be outlined under trips and interlocks, so they will not be mentioned here.

3) Each APRM has a set of four alarm lights on Panel 9-5 apron section below recorders:

a) Hi-Hi (Red light)

b) Hi (Amber light)

c) Downscale/Inop (White light)

d) Bypass (White light)

4) Each APRM has a set of five lights on the top of Panel 9-14 (Figure 6):

a) Hi-Hi (Red)

b) Hi (Amber)

c) Downscale (White)

d) Inop (White)

e) Bypass (White)

5) Each flow converter has these two lights on the top panel 9-14:

a) Comparator (Amber)

b) Upscale/Inop (Amber)

c. Interlocks and Trips

1) Rod Blocks

Block	Setpoint	When Bypassed
APRM: Downscale	<3%	Shutdown, Refuel, Startup modes
Hi	>12% >.66W + 42%	Run Mode Shutdown, Refuel, Start Modes*
Inop	1. Module unplugged 2. Less than 14 of assigned LPRM's in Operate 3. Function switch not in Operate	Never
Flow Converter: Mismatch Hi Inop	1. 10% flow mismatch 2. 110% either channel 3. Module unplugged	Never

2) Scram Trips

Scram	Setpoint	When Bypassed
Downscale with companion IRM Hi Hi**	<3%	Shutdown, Refuel, and Startup modes
Hi-Hi	>15% >.66W + 54%	Run mode Shutdown, Refuel and Startup modes*

Scram	Setpoint	When Bypassed
Inop	1. Module unplugged. 2. Less than 14 of assigned LPRMs in Operate 3. Function switch not in Operate	Never

* Technical Specifications specifies that the flow biased rod block and scram will never be bypassed. The way the circuitry is wired, either the flow biased trips or the fixed trips are always connected. Since the fixed references are more restrictive than the flow biased references, this condition is satisfied.

** Each IRM is assigned a companion APRM (and vice versa). Assignments are as Follows:

APRM CHANNEL	IRM CHANNEL
A	A
C	C
E	E
E	G
B	B
B	H
D	D
F	F

3. Controls Provided

   a. Recorder switches on Panel 9-5 - Switch recorders between APRMs and IRMs.

   b. Bypass switches on Panel 9-5

      1) Joystick type

      2) Allow bypassing only one APRM per RPS Channel at a time.

   c. Push to check pushbuttons 9-5 panel below recorders.

      1) Inserts rod block trip level to recorder input in place of core power signal.

2) Allows operator to check how far core power is from Rod Block trip level.

d. Meter unit on Panel 9-14 (Figure 7)

1) Trip Reset - Resets all seal-in trips at the top of Panel corresponding to that APRM, or assigned LPRM.

2) LPRM Bypassed Light - Indicates LPRM selected by selector switch and indicating on meter is bypassed.

3) Meter Expand Light - Indicates meter sensitivity has been increased by a factor of 10 (now reads 0 - 12.5% or 0 - 1 volt).

4) LPRM Selector Switch - Used in conjunction with function switch to select individual LPRM output for display on meter.

5) Function Switch - (Figure 8)

a) Seven Positions

(1) Average

(2) Count

(3) Flow

(4) A, B, C, D

b) Average Position - Meter reads core bulk thermal power (averaging amplifier output).

c) Count Position - Meter indicates number of assigned LPRMs which are in operate (5% per LPRM)

d) Flow Position - Meter reads per cent of rated total recirculation loop flow (output of flow converter)

e) A, B, C & D Position

Used in conjunction with LPRM selector switch to:

(1) Route individual LPRM output to meter (meter will read in watts/cm^2)

(2) Route calibration current to LPRM

(3) Route - 15 volts to calibrator (furnishes power to calibrator).

e. Inside Door on 9-14 (Figure 9)

1) APRM Mode Switch

a) 5 Positions

(1) Operate

(2) Standby

(3) Zero

(4) Power

(5) Power Flow

b) Operate Position - APRM operates normally as previously described.

c) Standby Position - Same as Operate except that it gives an Inop trip to warn operator if channel has not been bypassed - will give 1/2 scram if channel not bypassed.

d) Zero Position - Disconnects all inputs to averaging amplifier to check amplifier and meter zero adjustment.

e) Power Position

(1) Substitutes power potentiometer output for LPRM outputs as the input to averaging amplifier.

(2) Used when adjusting slope and bias circuit.

f) Power Flow Position

(1) In addition to e)(1) above, substitutes flow potentiometer output for the flow comparator output as the input to the slope and bias circuit.

(2) Also used when adjusting slope and bias circuit.

2) Meter Expand Switch

a) Three Positions

(1) Reverse

(2) Normal

(3) x 10

b) Reverse Position

(1) Meter reads opposite of its normal polarity, i.e. signal which read below zero before now will read above zero.

(2) Meter scale is expanded by a factor of 10, i.e. meter reads 0 - 1V DC instead of 0 - 10V DC.

c) Normal Position - Meter reads just as scale is marked (0 - 10V DC, 0 - 125%).

d) x 10 Position - Meter scale is expanded by a factor of 10.

e) This switch affects meter sensitivity only, and does not effect trip setpoints.

3) Power Potentiometer - Adjusts test power signal when function switch is in power or power flow.

4) Flow Potentiometer - Adjusts test flow signal when function switch is in power flow.

5) Monitor Pushbutton - Displays output of 10 volt regulated supply in calibrator on meter so that it can be adjusted with adjust potentiometer.

6) Adjust Potentiometer - Adjusts 10 volt regulated supply in calibrator.

7) Calibrator Thumbwheel Switches - Adjust calibrator output current.

C. OPERATIONAL SUMMARY

1. This section will briefly discuss these topics:

a. Operation of System During Startup

b. Calibration of APRMs

c. Rationale Behind Flow Biased Trip Levels

2. Operation During Startup

a. SRM - IRM Overlap

1) Approximately 1 Decade Overlap

a) APRM onscale (by definition and trip setting) at 3% power.

b) IRM Overlap - IRM reading (on range 9 or 10 = APRM x 2.564 i.e. IRM reading of 50 on range 10 = 19.5% APRM.

2) Limiting Condition (with Mode Switch in Run)

a) APRM must be onscale before companion IRM goes Hi-Hi.

b) IRM Hi-Hi with companion APRM downscale gives scram.

b. Transition from Startup to Run

1) More restrictive operationally than overlap discussed above.

2) Must be made with all APRMs between 3% and 15%, perferably between 5% and 12% since:

a) <3% in Run gives rod block thereby inhibiting further increases in power level from rod withdrawal.

b) >15% not in Run gives scram.

c) >12% not in Run gives rod block.

3. Calibration of APRMs.

a. Method of Calibration

1) All switches are left in their normal operating positions, except that APRM being calibrated is bypassed from panel 9-5.

2) Actual thermal power is obtained from heat balance by Process Computer, and Gain Adjustment factors (GAF) are determined

a) $$GAF = \frac{\text{desired reading}}{\text{actual reading}} = \frac{\text{thermal power heat balance}}{\text{rated thermal power}} \times 100\% \div \text{APRM reading.}$$

b) GAF is computed by computer program OD2.

3) Desired APRM readings determined

a) thermal power from heat balance/rated thermal power x 100% or

b) APRM reading x GAF from OD2 printout.

4) Adjust gain potentiometer for APRM's until desired reading is achieved on panel 9-14.

5) Remove bypass from panel 9-14.

b. Calibration of Trip Setpoints

1) APRM channel is bypassed and function switch is taken to power flow position.

2) By running power and flow potentiometers up and downscale, trip reference from slope and bias can be checked and adjusted at several points on the flow curve.

3) Function switch is returned to operate, trips reset and channel returned to service.

4) This is the reason for 6 APRM channels. Even with one from each RPS channel bypassed there are still enough to satisfy one out of two twice logic configuration (requires 4 operable channels).

c. Frequency of Calibration

1) Done at least weekly to compensate for Xenon, pattern changes, etc.

2) Checked and recalibrated if necessay after bypassing an input LPRM as

a) Bypassing a low reading LPRM will make APRM read higher, and

b) Bypassing a high reading LPRM will make APRM read low.

d. Calibration of scram and Rod Block Setpoint at TPF >DTPF

1) Technical Specification requires a reduction in APRM scram and Rod Block Setpoint if the core total peaking factor is greater than the design total peaking factor of 2.63 (Second section I for formulas)

2) Procedurally this is done by:

a) Calculating the APRM scram and rod block levels for 100% flow

b) Bypassing the APRM shannel to be calibrated

c) Placing APRM Mode switch to PWR Flow.

d) Adjusting flow to 100%, Power to scram trip level calculated in a)

e) Adjusting "scram trip" adjust (slope and bias circuits) to trip the scram trip unit.

f) Adjust power to rod block trip level calculated in a)

g) Adjust "rod block trip" adjust to trip the rod block trip unit.

h) Check setpoint by adjusting power.

i) APRM mode switch to operated.

j) Unbypass APRM and repeat for other APRM's.

e. Functional Test

1) Functional tests for nuclear instrumentations are exempted from the definition given in Section 1.0 of Technical Specifications, as no input to primary sensor (detector) is required.

2) Instead, output is run to scram trip level using power potentiometer with function switch in Power position.

3) The functional test causes half scram. This verifies proper operation of all trip relays.

4) Functional test is required weekly on APRMs.

2. Rationale Behind Flow Biased Trip Setpoints

a. Design Position

1) Flow biased scram and rod blocks are not required, i.e. no way to exceed fuel thermal limits with constant 120% scram.

2) No credit taken for flow biased trip levels in transient analysis.

3) Later plants (BWR 6's) with higher volumetric power densities will require flow biased scram.

4) These flow biased scrams will be delayed with a circuit whose time constant will approximate the fuel time constant.

This will be called a thermal power trip. The 120% scram will remain as an instantaneous backup to this thermal scram. These thermal power trips are being isstalled on some late model BWR/4 plants, and BWR/5's.

b. Selection of Trip Level Slope and Bias

1) Slope of trip line was selected to be parallel to 100% load line and higher power levels (60% or greater).

2) After slope was set, biases were selected so that at 100% flow:

a) Scram = 120%

b) Rod Block = 108%

c. Reason for Use of Recirculation Loop Flow Instead of Core Flow

1) Core flow signal noisy, i.e. much short term variation.

2) This noise would cause a number of spurious scrams.

3) Recirculation loop flow much steadier, so chance of spurious scrams greatly reduced.

d. Relationship of Trip Lines to Core Flow (Figure 10)

1) Core flow is not directly proportional to recirculation loop flow for 2 reasons:

a) Natural circulation effect due to decrease in density of coolant in core causes increase in flow with power at low power levels.

b) Increased hydraulic resistance to flow caused by large void fraction at higher power levels causes decrease in flow with power.

c) Hence, core flow is a fraction of both recirculation loop flow and power, and trip lines are not exactly linear when plotted on power-flow map.

d) Figure 10 shows APRM flow Biased Rod Block and Scram lines plotted on power flow map.

4. RELATIONSHIPS TO OTHER SYSTEMS

1. Inputs from Other Systems

   a. Flux Inputs from LPRM System to Averaging Amplifier.

   b. Flow Signal from Recirculation Loop Venturis to Flow Converter

   c. Mode Switch Contact Closure from Mode Switch Which Changes Hi and Hi Hi Trip Reference Inputs According to Reactor Mode (Run or Other than Run)

2. Outputs to Other Systems

   a. Scram Trip to Reactor Protection System.

   b. Rod Blocks to Reactor Manual Control System.

   c. Core Average Power to Process Computer.

   d. Reference APRM Signal to Rod Block Monitor.

   e. Power for LPRM Circuitry.

   f. Current Calibration Signal to LPRM System.

3. Power Supplies

   a. RPS Bus A

      1) APRM Channels A, C, E.

      2) LPRM Channel A

   b. RPS Bus B

      1) APRM Channels B, D, F

      2) LPRM Channel B

   c. Instrument Bus - Alarm lights on apron section of Panel 9-5.

   d. Essential Service Bus - Recorder power.

   e. 48 DC Battery Bus - Annunciator power.

I. TECHNICAL SPECIFICATIONS

1. Section 1.1, Safety Limit; 2.1 Limiting Safety System Setting (In part)

a. SAFETY LIMIT — LIMITING SAFETY SYSTEM SETTING

SAFETY LIMIT

FUEL CLADDING INTEGRITY

Applicability

Applies to the inter-related variables associated with fuel thermal behavior.

Objective

To establish limits which ensure the integrity of the fuel cladding.

Specifications

A. Reactor Pressure >800 psia and Core Flow >10% of Rated.

When the reactor pressure is greater than 800 psia, the existence of a minimum critical power ratio (MCPR) less than 1.05 shall constitute violation of the fuel cladding integrity safety limit.

LIMITING SAFETY SYSTEM SETTING

2.1 FUEL CLADDING INTEGRITY

Applicability

Applies to trip settings of the instruments and devices which are provided to prevent the reactor system safety limits from being exceeded.

Objective

To define the level of the process variables at which automatic protective action is initiated to prevent the fuel cladding integrity safety limit from being exceeded.

Specification

The limiting safety system setting shall be as specified below:

A. Neutron Flux Scram

1. APRM Flux Scram Trip Setting (Run Mode)

When the Mode Switch is in the RUN position, the APRM flux scram trip setting shall be:

$$S \leq (0.66W + 54\%)$$

where:

S = Setting in percent of rated thermal power (3293 MWt)

SAFETY LIMIT	LIMITING SAFETY SYSTEM SETTING
FUEL CLADDING INTEGRITY	2.1 FUEL CLADDING INTEGRITY

W = Loop recirculation rate in percent of rated (rated loop recirculation flow rate equals 34.2×10^6 lb/hr)

In the event of operation with a maximum total peaking factor (MTPF) greater than the design value of 2.63 the setting shall be modified as follows:

$$S \leq [0.66W + 54\%] \frac{2.63}{MTPF}$$

where:

MTPF = The value of the existing maximum total peaking factor.

For no combination of loop recirculation flow rate and core thermal power shall be APRM flux scram trip setting be allowed to exceed 120% of rated thermal power.

2. APRM - When the reactor mode switch is in the STARTUP position, the APRM scram shall be set at less than or equal to 15% of rated power.

3. APRM Rod Block Trip Setting

The APRM Rod block trip setting shall be:

B. Core Thermal Power Limit (Reactor Pressure <800 psia)

When the reactor pressure is less or equal to 800 psia or core coolant flow is less than 10% of rated, the core thermal power shall not exceed 823 MWt.

SAFETY LIMIT	LIMITING SAFETY SYSTEM SETTING
FUEL CLADDING INTEGRITY	FUEL CLADDING INTEGRITY
(about 25% of rated thermal power).	$S_{RB} \leq (0.66W + 42\%)$

where:

S_{RB} = Rod block setting in percent of rated thermal power (3293 MWt)

W = Loop recirculation flow rate in percent of rated (rated loop recirculation flow rate equals 34.2 x 10^6 lb/hr)

In the event of operation with a maximum total peaking factor (MTPF) greater than the design value of 2.63 the setting shall be modified as follows:

$$S_{RB} \leq [0.66W + 42\%] \frac{2.63}{MTPF}$$

where:

MTPF = The value of the existing maximum total peaking factor.

b. 2.1 Bases (Inpart)

1) In Summary:

a) Neutron Flux Scram

(1) APRM High Flux Scram Trip Setting (Run Mode)
The average power range monitoring (APRM) system, which is calibrated using heat balance data taken during steady-state conditions, reads in percent of rated power (3,293 MWt). Because fission chambers provide the basic input signals, the APRM system responds directly to average neutron flux. During transients, the instantaneous

rate of heat transfer from the fuel (reactor thermal power) is less than the instabtaneous neutron flux due to the time constant of the fuel. Therefore, during transient induced by disturbances, the thermal power of the fuel will be less than that indicated by the neutron flux at the scram setting. Analysis reported in Section 14 of the Final Safety Analysis Report demonstrated that with a 120 percent scram trip setting, none of the abnormal operational transients analyzed violate the fuel safety limit and there is a substantial margin from fuel damage. Therefore, use of a flow-biased scram provides even additional margin. Figure 2.12 shows the flow biased scram as a function of core flow.

An increase in the APRM scram setting would decrease the margin percent before the fuel cladding integrity safety limit is reached. The APRM scram setting was determined by an analysis of margins required to provide a reasonable range for maneuvering during operation. Reducing this operating margin would increase the frequency of spurious scrams, which have an adverse effect on reactor safety because of the resulting thermal stresses. Thus, the APRM setting was selected because it provides adequate margin for the fuel cladding integrity safety limit yet allows operating margin that reduces the possibility of unnecessary scrams.

The scram trip setting must be adjusted to ensure that the LHGR transient peak is not increased for any combination of MTPF and reactor core thermal power. The scram setting is adjusted in accordance with the formula in Specification 2.1.A.1, when the maximum total peaking factor is greater than 2.63.

Analysis of the limiting transients show that no scram adjustment is required to assure MCPR > 1.05 when the transient is initiated from MCPR >1.25.

(2) <u>APRM Flux Scram Trip Setting (Refuel or Start & Hot Standby Mode)</u>

For operation in the startup mode while the reactor is at low pressure, the APRM scram setting of 15 percent of rated power provides adequate thermal margin between the setpoint and the safety limit, 25 percent of rated. The margin is adequate to accommodate anticipated maneuvers associated with power plant startup. Effects of increasing pressure at zero or low void content are minor cold water from sources available during startup is not much colder than that already in the system, temperature coeffecients are small, and control rod patterns are constrained to be uniform by operating procedures backed up by the rod worth minimizer and the Rod Sequence Control System. Worth of individual rods is very low in a uniform rod pattern. Thus, all of possible sources of reactivity input, uniform control rod withdrawal is the most probable cause of significant power rise. Because the flux distribution associated with uniform rod withdrawals does not involve high local peaks, and because several rod must be moved to change power by a significant percentage of rated power, the rate of power rise is very slow. Generally the heat flux is in near equolibrium with the fission rate. In an assumed uniform rod withdrawal approach to the scram level, the rate of power rise is no more than 5 percent of rated power per minute, and the APRM system would be more than adequate to assure a scram before the power could exceed the safety limit. The 15 percent APRM scram remains active until the mode switch is placed in the RUN position. This switch occurs when reactor pressure is greater than 850 psig.

b) <u>APRM Control Rod Block</u>

Reactor power level may be varied by moving control rods or by varying the recirculation flow rate. The APRM system provides a control rod block to prevent rod withdrawal beyond a given point at constant recirculation flow rate, and thus to protect against the condition of a MCPR less than 1.05. This rod block trip setting, which is automatically varried with recirculation loop flow rate, prevents an increase in the reactor power level to excess values due to control rod withdrawal. The flow variable trip setting provides substantial margin from fuel damage, assuming a steady-state operation at the trip setting, over the entire recirculation flow range. The margin to the Safety Limit increases as the flow decreases for the specified trip setting vesrus flow relationship; therefore, the worst case MCPR which could occur during steady-state operation is at 108% of rated thermal power because of the APRM rod block trip setting. The actual power distribution in the core is established by specified control rod sequences and is monitored continuously by the in-core LPRM system. As with the APRM scram trip setting, the APRM rod block trip setting is adjusted downward if the maximum total peaking factor exceeds 2.63, thus preserving the APRM rod block safety margin.

2. Section 3.1

a. TABLE 3.1.A (In part)
REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENT

Min. No. of Operable Inst. Channels Per Trip System	Trip Function	Trip Level Setting	Modes in Which Function Must Be Operable: Shut-down	Refuel	Startup/Hot Standby	Run
	APRM					
2	High Flux	See Spec. 2.1.A.1				X
2	High Flux	≤15% rated power		X	X	(15)
2	Inoperative	(13)		X	X	X
2	Downscale	≥3 Indicated on Scale		(11)	(11)	X(12)

Notes For Table 3.1.A (Inpart)

11. The APRM downscale trip function is only sctive when the reactor mode switch is in run.

12. The APRM downscale trip is automatically bypassed when the IRM instrumentation is operable and not nigh.

13. Less than 14 operable LPRM's will cause a trip system trip.

15. The APPM 15% scram is bypassed in the Run Mode.

b. 3.1 Basis (In part)

Each protection trip system has one more APRM than is necessary to meet the minimum number reouired per channel. This allows the bypassing of one APRM per protection trip system for maintenance, testing or calibration.

3. Section 3.2

a. TABLE 3.2.c (In part)
INSTRUMENTATION THAT INITIATES ROD BLOCKS

Minimum No. Operable Per Trip Sys (5)	Function	Trip Level Setting
2	APRM Upscale (Flow Bias)	$\leq$0.66W + 42% (2)
2	APRM Upscale (Startup Mode) (8)	$\leq$12%
2	APRM Downscale (9)	$\geq$3%
2	APRM Inoperative	(10b)
2	Flow Bias Comparator	$\leq$10% difference in recirculation flow
2	Flow Bias Upscale	$\leq$110% recirculation flow

Notes for Table 3.2.C (In part)

2. W is the recirculation loop flow in percent of design. Trip level setting is in percent of rated power (3293 MWt). Total peaking factor greater than 2.63 are permitted at reduced power. See Specification 2.1 for APRM control rod block setpoint.

5. One instrument channel; i.e., one APRM or IRM or RBM; per trip system may be bypassed except only one of four SRM may be bypassed.

8. This function is bypassed when the mode switch is placed in Run.

9. This function is only active when the mode switch is in Run. This function is automatically bypassed when the IRM instrumentation is operable and not high.

10. The inoperative trips are produced by the following functions:

    b) APRM

        (1) Local "operate-calibrate" switch not in operate.

        (2) Less than 14 LPRM inputs.

        (3) Circuit boards not in circuit.

b. 3.2 Basis: (In part)

The APRM rod block function is flow biased and prevents a significant reduction in MCPR, especially during operation at

Revision ______________

Date ______________

BWR SYSTEMS

LESSON PLAN

A. TRAVERSING IN-CORE PROBE SYSTEM

B. REFERENCES

1. BWR Systems Manual Chapter 5.6
2. BFNP Traversing In-Core Probe Calibration System, GEK-32554
3. Flux Probing Monitor, GEK-13971H
4. Indexing Mechanism, GEK-34546B
5. Valve Control Monitor, GEK-62956A
6. BFNP FSAR 7.5
7. Reference Card File 5.6

C. OBJECTIVES

1. Learn the Purpose of the System.
2. Learn the Purpose and Function of the Components and Controls.
3. Understand the Operation of the System.

D. GENERAL DESCRIPTION

1. System Purpose
   a. Five identical traversing in-core probes (TIP's) are used to:
      1) Measure and record the axial neutron flux profile at 43 radial locations.
      2) Calibrate the fixed in-core detectors (Local Power Range Monitors)
2. System Description
   a. Detector is a miniature fission chamber attached to a flexible triaxial signal lead.

b. Shield Chamber

1) Normal, at-rest housing for detector

2) Provides personnel radiation shielding from irradiated detector.

3) Twelve foot minimum distance ensures that all parts of possibly irradiated detector or cable is shielded.

c. Drive Mechanism

1) Fractional horsepower motor

2) Drives detector from shield through guide tubes to top of core and back to shield.

d. Ball and shear valve provides the means to isolate the guide tubes if a TIP in-core dry tube should leak.

e. Indexer selects which dry tube will be used on a traverse.

f. Nitrogen purge is used to maintain the relative humidity in the guide tubes constant over the length of detector travel.

g. Operation is either automatic or manually controlled.

3. System Layout (Figure 2)

a. The TIP system was designed to achieve relative ease of access to critical components while maintaining necessary radiation shielding in spatially limited environs.

b. The under-vessel guide tubes are the most critical components as they are easily damaged and are inaccessible during normal operation.

c. Index mechanisms are also inaccessible during reactor operation, but are rugged and reliable.

d. All other components are accessible.

E. COMPONENT DESCRIPTION

1. Detector (Figure 3)

a. Miniature fission chamber similar to LPRM.

b. Constructed of titanium.

c. Coated internally with highly enriched uranium, 90% U^{235} (U^{235} content: 0.6 mg. Max.)

d. Insulating material - Forsterite

e. Filled with Argon gas under pressure of 91.5 cm Hg.

f. Active portion is about 0.2" O.D. by 1" long.

g. Neutron sensitivity 8.17×10^{-18} Amp/nv $\pm$ 20%

h. Gamma sensitivity 3×10^{-14} Amp/R/h max.

i. Neutron Flux Operating range 2.8×10^{12} to 2.8×10^{14} maximum.

j. Operating voltage (detector polarizing) 100-200 VDC

k. Traverses the entire active length of the core through a dry tube in the LPRM detector tube.

2. Detector Drive Cable/Signal Lead (Figure 3)

a. Coaxial cable about 0.25" O.D. by 150' length

b. Helical wrap of carbon steel covers entire length of drive cable.

1) Provides a low friction means of driving detector.

2) Protect signal cable.

3) Dry lubricated with molybdenum disulfite.

c. Sheath stainless steel

d. Inner conductor stainless steel

e. Insulating material magnesia

f. Operating environment

1) Relative humidity - Less than 50%

2) Temperature (Max.) 320°C (608°F) Ambient Temperature 290°C (554°F)

g. Exposure Life 10^{13} nvt

3. Drive Mechanism (Figure 4)

   a. The purpose of the drive mechanism is to provide forward or reverse and high or low-speed detector cable drive on commands from the drive control unit.

   b. Consists of an air tight metal enclosure housing an Eaton drive motor and a Gleason cable reel assembly.

   c. Drive Motor

      1) The 1/2 Hp. drive motor provides power to the output shaft through an eddy-current clutch.

      2) The eddy-current clutch shaft is connected through a gear reducer and a 1:1 chain drive to the output load shaft.

      3) The output load shaft feeds a friction-slip clutch. The clutch disc is directly coupled to a hobbed wheel which drives the detector by engaging the helix wrap on the detector cable.

      4) The shaft of the friction slip clutch passes through the drive box housing and is chain and sprocket coupled to:

         a) Veedor-Root Counter

         b) 40 turn potentiometer

      5) The friction-slip clutch limits the drive torque applied to the detector cable.

         Caution: Slip clutch is normally torqued to 85 in.-lbs. The helix on the TIP cable will stand up to 100 in.-lbs. torque before deforming. Under no case should the slip clutch be set >250 in.-lbs. Exceeding this limit will immediately destry the detector cable.

      6) Motor is reversible by rotation phase reversal.

      7) Provides two speeds.

         a) 15'/min.

         b) 60'/min.

c) By an internal eddy-current clutch.

i. The degree of coupling between the shaft and load is proportional to the current in the clutch coil.

ii. The current is determined by either automatic sensors or manual controls on the drive control unit.

iii. The clutch controls the torque between the armature-shaft and the clutch-shaft quills by magnetic induction.

8) The motor is equipped with a fail-safe friction broke to prevent inertial overshoot.

d. Veeder-Root Counter

1) Purpose is to provide a digital display readout of detector position on the Drive Control Unit.

2) Signal is from four identical, ten-position switches. (0000 to 9999)

e. Forty-turn Potentiometer

1) Purpose is to supply a d-c voltage analog signal of detector position to:

a) x-y recorder on TIP Control Console (back panel)

b) Plant process computer

4. Gleason Reel Assembly (Figure 5)

a. Consists of:

1) A takeup reel 20" diameter which stores the detector drive cable.

2) A tie plate mounted on the takeup reel, that is a signal connector between the drive cable and smooth (unwrapped) triaxial signal cable.

3) Two smaller drums store the smooth signal lead.

a) Drum "A" is physically attached to the takeup reel.

b) Drum "B" is stationary and stores most of the smooth signal lead when the detector is in the shield.

4) The transfer pulley distributes smooth signal lead between the smaller drums when detector cable is moving.

b. Operation

1) As the detector is driven forward by the hobbed wheel of the drive mechanism, the linear motion of the cable causes the takeup reel and attached drum "A" to rotate.

2) Moving drum "A" exerts a tensioning force on the smooth cable through the transfer pulley.

3) This force causes the transfer pulley assembly to rotate in the same direction as the takeup reel.

a) Strips smooth cable from stationary drum "B" laying it on rotating drum "A".

4) Smooth cable continues to be stripped off the stationary drum "B" and wrapped on the rotating drum "A" as the detector is driven toward the core.

5) Both the takeup reel and transfer pulley tension the springs when rotating "forward" to prevent backlash and cable slack.

c. The reel assembly was designed to eliminate signal loss and noise associated with rotating signal pickups (converts rotary motion to linear cable travel).

1) Uses physically fixed couplings at the tie plate and drive mechanism housing.

2) Signal lead transfer between fixed connectors compensates for rotary motion and provides a stationary signal pickup.

5. Shield Chamber (Figure 6)

a. Purpose of the shield chamber is to provide personnel shielding from a recently withdrawn detector.

b. Small cask, about 14" diameter by 20" long.

c. Filled with lead shot (total weight = chamber and lead 1150 lbs.)

1) Has a fill port for lead.

2) Has a lifting eye for rigging.

d. The guide tube passes through the radial center.

e. The limit switch in longitudinal center.

   1) Prevents further withdrawal (reverse) of detector.

   2) Opens ball valve when detector is moved forward and drive motor is energized.

   3) Lights In-Shield light on Drive Control Unit of TIP Control Panels (back panel area).

   4) The limit switch is actuated by the detector or drive cable.

      a) When either is under the switch circuits are completed to open the ball valve provided drive power is available.

      b) When the detector is behind the limit switch contacts are opened in the reverse circuits de-energizing the drive motor.

   Caution: This limit switch has been known to fail such that the detector fails to stop in-shield. Difference in known digital in-shield position to in-shield light on Drive Control Unit could be indicative of this problem.

6. Shear Valve (Figure 7)

   a. Purpose is to provide an emergency means of sealing a guide tube if:

      1) The TIP dry tube (in-core) should leak and

      2) The TIP detector cannot be retracted preventing ball valve closure.

   b. Controlled by a key-lock switch on the Valve Control Monitor drawer.

   c. Explosive valve

      1) Squib detonation circuit

      2) Two primers; two firing circuits; one indication circuit

      3) Firing circuits continuously monitored.

      4) Indication circuit is continuously monitored. Circuit is broken, when squib is detonated, by indicating link.

d. "Fire" position applies >4 amps to squib.

e. Wedge shaped guillotine ensures guide tube seal even with detector cable inside.

1) Aluminum seal - after is deformed to seal detector cable to guide tube space.

7. Ball Valve (Figure 8)

a. A solenoid-operated valve that is installed in the detector guide tube between the drive mechanism and the indexing mechanism to prevent leakage of contaminated coolant from the reactor vessel into the drive mechanism if a leak develops in the reactor core.

b. Purpose is to provide the normal means of sealing guide tube. Normally shut except during traverses.

c. Held closed by a fail-safe spring

d. Opened by application of 110 VAC power to the solenoid coil supplied from the drive mechanism.

e. Circuitry allows five seconds for ball valve to open. If not full open as detected by limit switch:

1) De-energizes drive mechanisms

2) Preventing detector and drive cable damage.

8. Index Mechanism (Figure 9)

a. Purpose is to provide precise coupling between a fixed guide tube and any one of ten removable guide tubes that lead to in-core positions.

b. Components

1) Guide paths to and from indexer

a) Fixed guide tubes link the indexer to the drive mechanisms.

b) Stationary guide tubes provide paths from the indexer to the core. These guide tubes are removable for under vessel work and are number coded for ease of reinstallation.

2) Mechanically consists of a Geneva - gear and a movable guide tube.

3) Electrically comprised of

a) Drive motor

b) Limit and position switches necessary for control circuits.

c. Control of Indexer

1) Controlled by channel selector switch (10 position) on the Drive Control Unit.

2) Applies power to the motor.

3) The motor turns a gear with a locking cam and a crankpin.

4) The locking cam imparts motion to the Geneva - gear.

5) As the Geneva - gear turns the crankpin engages continuing the motion.

6) At a half revolution the locking cam engages the next position.

7) Rotation continues until the signal from position switch S-1 matches the channel selected on the Drive Control Unit. (S-1 is hidden from view on Figure 9).

a) S-1 is driven by a chain and sprocket directly off the Geneva-gear.

b) S-1 is a triple deck, 10 position rotary switch.

i. Deck 1 sends a signal to the Drive Control Unit control circuitry.

ii. Deck 2 is used to de-energize the motor when indexer is at selected position.

iii. Deck 3 is not used.

8) However, limit switch S-3 keeps the motor energized until the crankpin actuates S-3.

9. Purge System (Figure 10)

   a. Purpose is to maintain the relative humidity in the guide tubes at a constant value over the length of detector travel and maintain a dry atmosphere in the drive mechanism and indexer enclosures.

   b. 1) Eliminate corrosion of helical wrap (carbon steel).

      2) Reduces chance of insulation breakdown and signal loss.

   b. Drive Mechanism Purge System

      1) Uses dry air from the Control Air System (-40^{o}F dewpoint)

         a) Pressure is reduced from about 95 psig to 5 psig

         b) Flow is controlled to each drive mechanism at 1.5 SCF/HR

      2) Drive mechanism enclosure is airtight.

      3) Dry air atmosphere reduces helical wrap corrosion of stored detector cable.

      Caution: Before opening drive mechanism enclosure secure purge system to prevent possibility of radioactive contamination spread from activated corrosion products.

   c. Indexer Purge System

      1) N_2 system supplied to each indexer.

         a) Indexer enclosure is airtight (Figure 9).

         b) Internal pressure control valve maintains 7" H_2O above drywell containment pressure.

         c) Internal blowout valve opens if indexer pressure >5 psig above containment.

         d) Maximum flow rate of 140 SCF per day allowed through the indexers and the guide tubes.

      2) System maximumflow rate is set at 140 SCF per day.

         a) By opening exhaust valve and adjusting flow through rotameter.

         b) Flow is sufficient to maintain pressure in remaining indexers if line to one indexer ruptures or pressure control valve fails.

3) When installing or re-installing removable guide tubes the indexer purge system is activated and the guide tube to dry tube penetration connection is cracked to purge and fill guide tubes.

4) Controlled by purge switch on the Valve Control Monitor. (Opens solenoid valve on Figure 10).

10. Four-Way Connectors (Figure 11)

a. Purpose of the connectors is to provide a path for five indexers to the common channel (10) at core position 32-33.

b. Guide tubes from TIP indexers A, B, and C meet at first four-way connector.

c. Guide tube from first four-way connector and TIP's D and E meet at second four-way connector.

d. Guide tube from second four-way connector leads to core position 32-33 (Channel 10).

11. Guide Tubes

a. Part of LPRM detector assembly

b. Inner surface of the guide tubing between the reactor vessel and the drive mechanism is coated with a ceramic bonded lubricant to reduce friction.

c. Guide tube inner surface is nitrided within the reactor vessel.

F. CONTROLS AND INSTRUMENTATION

1. Consists of (Figure 12)

a. Flux Probing Monitor

b. Valve Control Monitor

c. Drive Control Unit

d. X - Y Recorder

e. Plant Process Computer

2. Flux Probing Monitor (Figure 13)

   a. Purpose is to supply high voltage to the TIP detectors and amplify the flux signal from the detectors.

   b. Components

      1) Two low voltage power supplies for flux amplifiers.

      2) A calibration card for calibrating the flux amplifiers.

      3) A high voltage power supply and flux amplifier for each TIP detector.

   c. Signal output of flux amplifiers is fed to X-Y Recorder and the Process Computer.

   d. Controls and Indication

	Device	Position	Function
1)	Switch S-1 (Meter selector switch)	A Bus -	Connects meter M-1 to -10V DC output of low voltage power supply PS7.
		A Bus +	Connects meter M-1 to +10V DC output of power supply PS7.
		B Bus -	Connects meter M-1 to -10V DC output of power supply PS8.
		B Bus +	Connects meter M-1 to +10V DC output of power supply PS8.
		Channel A thru Channel E (Refers to TIP subsystem)	Connects meter M-1 to calibrate output of flux amplifier for the detector selected. (Used during calibration.)
2)	Switch S-2 (Channel selector switch)	Off	Disconnects X-Y Recorder from TIP system.
		Channel A thru Channel E (Refers to TIP subsystem)	Connects X-Y Recorder, Y-axis to selected flux amplifier; X-axis to proper position potentiometer (40-turn)

	Device	Position	Function
3)	Meter M-1	0 - 125 (upper scale)	Indicates "percent power" when S-1 is at Channel A thru Channel E position.
		0 - 10 (lower scale)	Indicates power supply voltage when S-1 is in any of the "Bus" positions. (During calibration indicates flux amplifier output when S-1 is in Channel A thru Channel E)

3. Valve Control Monitor (Figure 14)

   a. Purpose is to house control and indication circuits for the shear valve, ball valve and N_2 purge system.

   b. Each drawer has controls for two TIP subsystems except for one drawer which has only TIP (Channel E).

   c. Shear Valve Control and Indication

	Device	Position	Function
1)	Key Lock Switch S-1	Monitor	Key switch is open.
		Fire	Detonates explosive shear valve
2)	Squib Monitor	Lit	Indicates squib has detonated or circuit to explosive charge is open.
3)	Shear Valve Monitor (light)	Lit	Indicates shear valve has actuated.

   d. Ball Valve Indication

	Device	Position	Function
1)	Ball Valve Open (light)	Lit	Indicates ball valve is open.
2)	Ball Valve Closed (light)	Lit	Indicates ball valve is closed
3)	Time Delay	Lit	Indicates ball valve is open and interlock circuit is complete.

	Device	Position	Function
4)	F 5 (Illuminated fuse)	Lit	Indicates that the Group II containment isolation bus fuse has not blown.

e. Nitrogen Purge System Control and Indication

	Device	Position	Function
1)	Purge Switch S-3)	Off	Deactivates Indexer Purge System. (See Figure 10)
		On	Opens solenoid valve in Indexer purge system.
2)	Purge (light)	Lit	Indicates indexer purge system is activated.

4. Drive Control Unit (Figure 15)

a. Purpose of the unit is to examine switch positions, automatic functions and predetermined core dimension limits to logically issue drive signals which will not damage the detector or drive cable.

b. Components:

1) Detector Position digital display
2) Core Limit digital display
3) Indicating Lights
4) Channel Select switch
5) Core Limit switch
6) Manual switch
7) Manual Valve Control switch
8) Mode switch
9) Ready light
10) Auto Start Pushbutton
11) Scan switch
12) Low speed switch

c. Modes of Operation

1) Automatic Mode drives the detector from the shield chamber to the selected in-core position and plots the neutron flux profile as the detector is withdrawn automatically.

2) Manual Mode is an alternative to automatic scanning of the core and provides incremental positioning of the detector at the selected in-core position.

d. Definitions

1) Channel - A position of the channel select switch (1 - 10) that corresponds to the particular in-core position of a TIP dry tube (inside LPRM string). Each channel select switch position is a different in-core position with the exception of Channel 10 which is common.

Example:

TIP Machine	Channel Selected	In-Core Position
A	2	61 - 49
B	2	08 - 25
C	2	24 - 09
D	10	32 - 33
E	10	32 - 33

2) Detector Position Digital Display

a) 0000 - Reference point. about one foot behind the indexer (away from the core).

b) 9800 - In-shield position - Counter increases as detector is driven forward (toward core) passing reference at indexer and continues to increase.

3) Core Bottom Limit - Some predetermined positive value that corresponds to the bottom of active fuel. Differs for each TIP channel (including 10) because length of run from shield to core position is different.

4) Core Top Limit - Same as bottom limit but indicates top of active fuel for selected channel.

5) Scan - Withdrawal of detector from core top to core bottom with plot of neutron flux profile - usually with subsequent storage of data by process computer.

e. Controls and Indication

	Device	Position	Function
1)	Channel Select (switch, S-1)	1 thru 10	Selects in-core position to which indexer must align.
2)	Auto Start (pushbutton, S-2)	Pressed	Provides automatic detector drive when Mode Switch S-7 is set to Auto and Manual Switch S-3 is set to Off.
3)	Manual (switch, S-3)	Off	Enables the Auto position of Mode Switch S-7.
		FWD	Drives detector to top of core - overrides Auto position of Mode Switch S-7.
		REV	Drives detector from core top to shield - overrides Auto position of Mode Switch S-7..
4)	Scan (switch, S-4)	Off	Makes scan (record) a function of detector position and independent of operator control.
		On	Makes a scan (record) if detector is between core limits.
5)	Low (speed) (switch, S-5)	Off	Makes low-speed drive a function of detector position and independent of operator control
		On	Initiates continuous low-speed detector drive.
6)	Core Limit (switch, S-6)	Top	Permits digital display of selected channel pre-programmed top-core limit.
		Bottom	As above, except core bottom limit is displayed.
7.	Mode	Off	De-energizes power supplies in Drive Control Unit.

Device	Position	Function
	Manual	Positions detector in conjunction with the FWD and REV positions of Manual switch S-3.
	Auto	Permits automatic mode of operation when Auto start S-2 is pressed.
8) Manual Valve Control (switch, S-9)	Closed	Closes ball valve.
	Open	Opens ball valve without energizing the drive motor in the drive mechanism.
9) Detector Position	Illuminated digits	Continuous digital display of detector position.
10) Core Limit	Illuminated digits	Static digital display of preprogrammed core-top or -bottom limits of selected channel.
11) Ready (light)	Lit	Indicates that indexer is properly aligned to selected channel.
12) Core Top (light)	Lit	Detector is at top of core.
13) In-Core (light)	Lit	Detector is above core-bottom limit.
14) In-shield (light)	Lit	Detector is in shield chamber.
15) Scan (light)	Lit	Axial flux profile is being recorded.
16) Low (speed) (light)	Lit	Detector is being driven at low-speed (15'/min.).
17) Rev (reverse) (light)	Lit	Detector moving away from top of core.
18) Fwd (forward) (light)	Lit	Detector moving toward top of core.
19) Valve (light)	Lit dimly	Ball valve is open.
	Lit brightly	Ball valve is closed.

5. X-Y Recorder (Figure 16)

   a. Purpose is to plot a graph of neutron flux versus detector position.

   b. Components are:

      1) The plotter

      2) An X-axis and a Y-axis control section

         a) Range switch

         b) Vernier adjust

         c) Zero adjust

         d) Test jacks

      3) Power switch

      4) Pen switch

      5) Chart switch

   c. Operates during core traversing cycle.

      1) Automatic mode, on detector withdrawal from top of core.

      2) a) Mode switch at Auto.

         b) Scan switch at Off.

         c) TIP being run is selected on Flux Probing Monitor, Channel Selector Switch S-2 (Channel A thru Channel E).

      3) Operates any time the Scan switch is On and the detector is between core-bottom and core-top limits regardless of Mode switch position (Auto or Manual).

   d. Drawer Controls

	Device	Position	Function
1)	Power (switch)	On	Power applied to recorder servo's.
		Off	Power to servo's off.

Device	Position	Function
2) Power (light)	Lit (red)	Same as On.
3) Pen (switch)	Down	Places pen on chart paper.
	Up	Pen drops automatically to chart paper when detector reaches core-top limit.
4) Chart (switch)	Hold	Electrostatic charge holds paper on recorder.
	Release	Charge is dissipated.

5) All other controls to be adjusted by qualified instrument personnel only.

6. Process Computer

a. Purpose to:

1) Calculate gain adjustment factors (GAF's) for LPRM's; needed as LPRM detector fuel depletion occurs (about every 30 full power days).

2) Calculated substitute data for an out-of-service LPRM.

3) Uses TIP trace (scan) data for 1) and 2).

b. Inputs to Computer from TIP System

1) Detector position signal from Drive Control Unit.

2) Neutron flux level signal from Flux Probing Monitor.

3) Channel selected from Indexer switch S-1 through Drive Control Unit.

c. Computer:

1) Types out data for each TIP trace (scan) run.

a) Which TIP machine

b) Which TIP channel

c) Core coordinates of selected channel

d) Neutron flux level at 24 nodes over the in-core length of detector travel.

2) Computer also stores the above data in its memory circuits.

G. SYSTEM OPERATION

1. Modes of Operation

a. Automatic Operation Sequence (Figures 13 & 15)

1) Channel selected on Flux Probing Monitor (Figure 13).

2) a) Sends selected TIP signals to X-Y Recorder.

b) Corresponds to TIP detector being run.

2) Mode switch at Auto (Figure 15).

3) Manual switch at Off.

4) Low-speed switch in Off.

5) Channel selected - corresponds to desired core location.

6) Ready light lit.

7) Press Auto Start pushbutton.

8) Detector moves from shield chamber through indexer at low speed (15'/min.).

9) Past indexer (reference point of 0000) speed switches to fast (60'/min.).

10) At core bottom limit speed changes to slow.

11) At core top limit detector stops and reverses direction.

12) X-Y Recorder pen drops automatically to paper.

Note: Scan or record (TIP trace) is made now because top of core is a better reference and even tension is exerted on the detector producing smoother travel.

13) Scan light lit.

14) At core bottom limit the speed increases to fast.

15) Detector stops at 0000 reference - about 1' behind indexer (toward shield).

16) New channel may be selected and process repeated.

b. Manual Operation Sequence (Figures 13, 15)

1) Used when

a) The flux level at a specific LPRM (A, B, C, or D) must be known.

b) Suggested when traversing the common channel (10) at core location 32-33.

i. Runs are longer.

ii. At least one four-way connector must be traversed.

2) TIP being run must be selected on Flux Probing Monitor (Figure 13).

3) Mode switch in Man (manual).

4) Low-speed switch at either Off or On.
Note: Low speed is preferred for channel 10 traverse.

5) Direction and drive controlled by Manual switch; Fwd or Rev (forward or reverse).

6) Drive detector to top of core by Manual switch at Fwd.

7) Detector stops automatically at core top limit.
Note: Detector may be stopped at any point by going to Off with Manual switch.

8) Scans automatically on withdrawal (Rev).

9) Detector will drive to shield chamber unless stopped at Indexer reference point (0000).
Note: Manual Rev is the only way to move detector from Indexer to Shield upon completion of TIP scans regardless of mode of operation.

c. Manual Drive (Figure 4)

1) Used to probe guide tube runs to determine core-top limits.

2) Drive chain from drive mechanism gear head to mechanical slip clutch must be removed.

3) Manual Valve Control switch on the Drive Control Unit must be at Open to open ball valve (Figure 15).

4) Detector is moved by attaching a hand crank to the load shaft. Note: All necessary precautions should be observed before opening Drive Mechanism enclosure.

2. TIP Traces (Figures 17, 18 & 19)

a. Purpose is to produce a visual representation of neutron flux profile.

b. Coordinates (Figure 17)

1) Y-axis is watts/cm^2 .

2) X-axis is fuel length expressed in:

a) Fuel length in inches from core bottom.

b) Nodes, a computer scale equal to 6" of length, numbered from core bottom.

c) Rod position, equal to 3" of length, numbered from core top.

c. S/P

1) At the bottom margin, indicate fuel rod spacers.

2) About 18" intervals

3) TIP trace usually shows shadows or flux dips from these spacers.

4) Indicated on Figure 17 at about rod position 30.

d. LPRM Detectors

1) Indicated by appropriate letter in a hexagon at correct core height.

2) At bottom margin

3) The shadow cast by LPRM B is indicated on Figure 17.

e. Data Box Indicates:

1) Date and time of traverse.

2) Which TIP machine was used.

3) The channel selected and

4) The location of the LPRM string.

5) The cross and numbers indicate the heights of the control rods around the LPRM.

f. Common Channel Traces (Figures 18 & 19)

1) During an LPRM calibration the common channel is first traversed by each TIP machine.

2) The computer normalizes or averages the five scans to cross calibrate the TIP's themselves before using TIP outputs to calibrate LPRM's.

3) Figures 18 & 19 should overlay to show why this is necessary.

4) Nucleate boling begins about node 4 on these figures (node 11 on Figure 17) which leads to slight, local, instantaneous flux changes and accounts for the differences in the traces.

H. SYSTEM INTERRELATIONSHIPS

1. Local Power Range Monitoring System

a. The TIP's are used primarily to calibrate LPRM's.

b. LPRM's must be recalibrated:

1) At each testing plateau during Startup Testing.

2) Every Full Power Month to recover sensitivity lost due to detector fuel depletion.

a) There is less U^{235} in the detector to fission by the same number of neutrons.

b) Signal is increased electronically to compensate for this change.

3) When control rod sequence is exchanged from A to B or back.

4) When operating mode has changed significantly.

a) An example would be loss of a heater string which would cause an increase in Base Crit Codes which indicate that the computer is unable to derive a value for LPRM's from the last TIP normalization data that compares favorably to heat balance core power.

5) After refueling:

a) Usually a number of LPRM's are replaced during a refuel outage.

b) Core has been altered and radial and axial profiles have been changed.

c) Two months have usually elapsed and electronic circuits should be checked prior to power range operation.

2. Process Computer

a. At equilibrium xenon and steady state power TIP scans are performed according to the procedure for On-Demand Function-01 of the process computer.

b. The computer compares the TIP data to present LPRM readings.

c. The computer calculates gain adjustment factors that will make the LPRM's agree with the TIP data.

d. Gain adjustments are performed on the LPRM cards by a qualified instrument technician.

3. Electrical Supplies

a. 120 VAC Instrument and Control

b. 24 VDC System

4. Nitrogen Purge

a. From inerting makeup supply line

5. Control Air Purge

6. Group 8 Isolation

a. Initiated by -2 psi in drywell

b. On this signal any TIP not in the shield chamber:

1) Is automatically transferred to the Manual Reverse mode of operation. (Result of relay logic in Drive Control Unit)

2) When the detector is In-Shield as indicated by the limit switch the ball valve is closed.

I. TECHNICAL SPECIFICATIONS

a. There are no Technical Specifications associated with the TIP system.

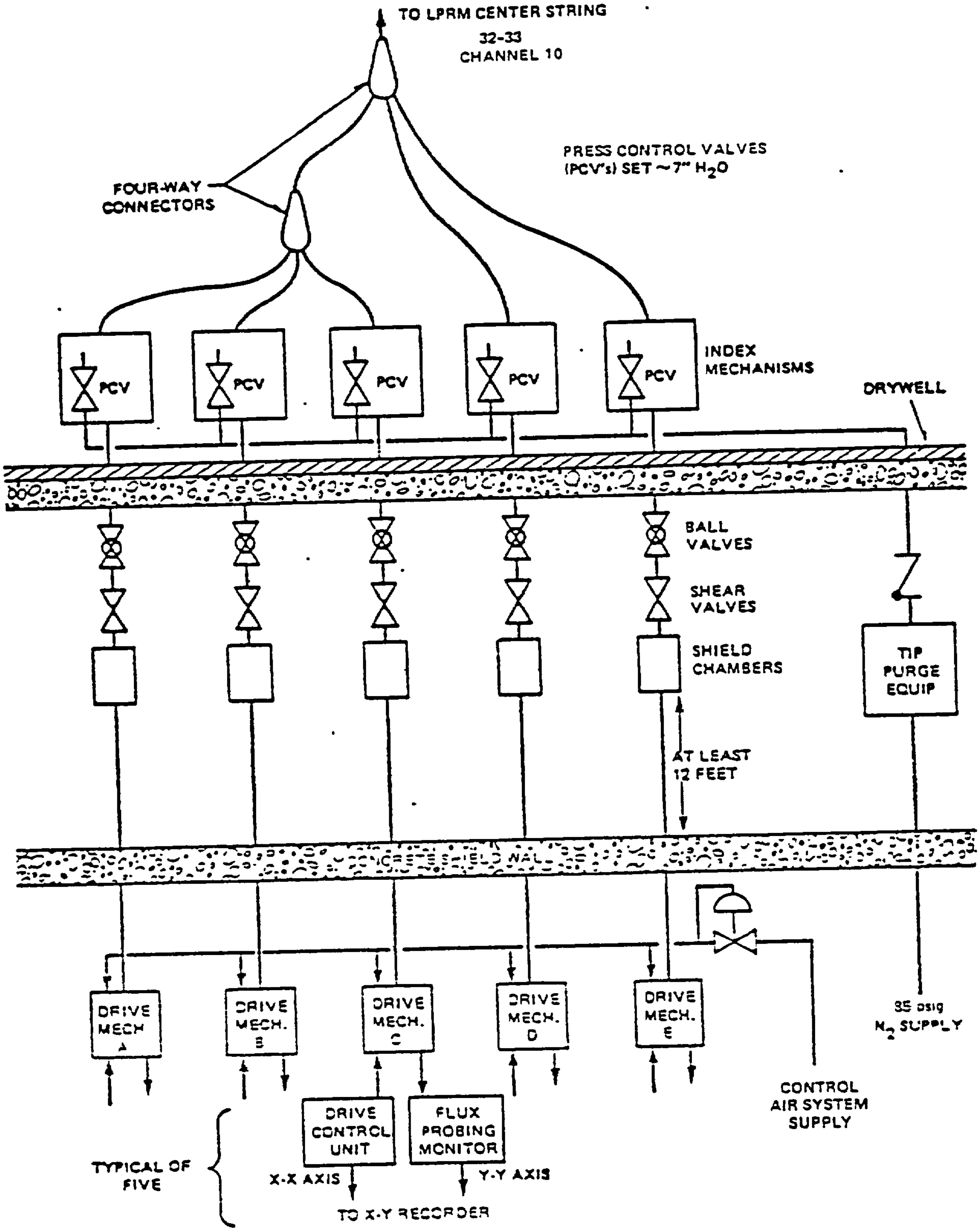

FIGURE 1. TRAVERSING IN-CORE PROBE SYSTEM

Revision ________________

Date ________________

BWR SYSTEMS

LESSON PLAN

A. ROD WORTH MINIMIZER

B. REFERENCES

1. BWR Systems Manual Chapter 6.1
2. Process Computer GEK 39439B
3. Brown's Ferry Technical Specifications
4. Reference Card File #6.1

C. OBJECTIVES

1. Fully understand the purpose of the system and its design basis.
2. Learn major system components.
3. Understand significant interlocks and blocks.
4. Relationships between the rod worth minimizer and other systems
5. Technical specifications governing the system.

D. GENERAL DESCRIPTION

1. Design basis - The design basis of the rod worth minimizer (RWM) is to serve as a backup to procedural control to limit control rod worths during startup and low power operation, so that in the event of a control rod drop from the reactor core the reactivity addition rate would not lead to damage of the primary coolant system not to significant fuel damage.

2. Purpose

   a. The RWM acts as an enforcer of pre-stored rod patterns and generates rod blocks if significant deviation from the program pattern (sequence) is detected.

   b. The programmed withdrawal sequence is designed to limit the maximum worth of any single control rod.

   c. The control rod velocity limiter limits the rate of reactivity addition in the event of a rod drop accident by limiting maximum rod drop speed to 3.11 feet per second.

d. The RWM in conjunction with the control rod velocity limiter, limits the amount of fuel damage that would occur during a rod drop accident.

Note: The rod sequence control system (RSCS) is a backup system to the RWM. It independently imposes restrictions on control rod movement to mitigate the effects of a postulated rod drop accident. See the RSCS lesson plan for details.

3. Rod drop accident

a. A control rod drop accident is postulated to occur as follows:

1) The control rod drive mechanism separates from the control rod blade.

2) The drive mechanism is withdrawn.

3) The blade sticks in the core and does not follow the drive mechanism.

4) The blade then breaks free and drops to the position of the drive mechanism, rapidly inserting reactivity and generating heat in the fuel.

5) The negative doppler coefficient will turn the power excursion and a reactor scram will complete the shutdown.

b. The accident is analyzed over the full spectrum of power conditions with results presented in the FSAR for three sets of initial conditions (for an in sequence rod)

1) Reactor critical at 10^{-6}% power, moderator and fuel at 68°F; rod worth for dropped rod = 0.025 ΔK.

2) Reactor critical at 10^{-4}% power; moderator and fuel at 547°F; rod worth for dropped rod = 0.025 ΔK.

3) Reactor critical at 10% power; moderator and fuel at 547°F rod worth for dropped rod = 0.038 ΔK.

c. Several assumptions were used in the analyses

1) The velocity at which the control rod falls out of the core is assumed to be 5 ft/sec.

Note: This is conservative in that the control rod velocity limiter limits rod falling speed to 3.11 ft/sec.

2) Control rod scram motion is assumed to start at ~200 msec after neutron flux has attained 120% of rated flux.

Note: This assumption allows the power transient to be terminated by the doppler coefficient and is particulary conservative for the very low power level cases since the IRM high flux level scram would be reached earlier than the 120% scram.

3) No credit is taken for the negative reactivity resulting from moderator increased temperature or void formation since the time constant for heat transfer between fuel and moderator is long compared with the time required for rod motion.

4) No credit is taken for prompt negative reactivity effect of heating in the moderator due to gamma heating and neutron thermalization.

d. Fuel damage is defined as perforation of the cladding allowing fission products to the coolant.

Condition	Enthalpy of fuel (cal/gram)
cladding perforation	170
onset of UO_2 centerline melting	220
UO_2 melting complete	280
Instantaneous fragmentation and dispersal of fuel rods (due to UO_2 vapor pressure)	425

e. Fuel damage will probably occur as a result of the worst case rod drop accident which is the hot standby critical case.

1) It has been calculated that ~330 fuel rods will have enthalpies >170 cal/gram.

2) Maximum UO_2 enthalpy is calculated to be 220 cal/gram.

3) Essentially no fuel will melt because fuel melting occurs in the range 220-280 cal/gram

f. The power transient at 10% power is less severe than at hot standby:

1) ~50 fuel rods have enthalpies >170 cal/gram

2) Peak UO_2 enthalpy is 250 cal/gram.

3) ~50 pounds of UO_2 have enthalpies >220 cal/gram.

4) Because fewer fuel rods are perforated and because shutdown cooling would be in operation allowing no reactivity release to the main condenser, the radiological results of the cold rod drop accident are insignificant when compared to the hot standby case.

h. All of the peak enthalpies are far below 425 cal/gram, which is the threshold for immediate rupture of fuel rods due to UO_2 vapor pressure, and are well below the design limit of 280 cal/gram so that no damaging pressure pulses occur as a result of a rod drop accident and the only expected damage is the failed fuel rods.

i. If a rod drop accident were to occur, plant response would be automatically initiated to contain fission products and limit the severity of the transient as indicated by figure 2.

1) This does not include the effects of the negative doppler coefficient which would be the first plant response to a rod drop accident.

2) The maximum radiation exposures at the site boundary have been conservatively calculated to be well below the valves set forth in 10 CFR 100 for all analyzed rod drop accidents.

4. Any discussion of the RWM system makes use of a number of terms peculiar to the RWM. These terms are listed and defined below.

a. Operating Sequence. The operating sequence is the schedule to be followed by the plant operator when withdrawing or inserting control rods. The sequence is precalculated to minimize individual rod worths and reactivity insertion rates, based on the core dimensions of the particular plant at which it is used. It is printed out for the operator's use when starting up or shutting down the reactor, and is also loaded into the computer memory for use by the RWM program. The sequence identifies the control rods by X-Y coordinates and specifies the notch position (even numbers between 0 and 48) to which each rod should power, rods are inserted in reverse order of their withdrawal. Although sequences vary depending on individual reactor size and characteristics, they all generally begin by withdrawing fully (to position 48) approximately half the rods in the core. At this point, the rod position distribution is referred to as the "black/white pattern", so-called because the fully withdrawn rods are distributed in a checkerboard pattern across the core cross-section, such that every other rod along either an X or a Y coordinate will be fully withdrawn while the alternate rods remain fully inserted. Attainment of this pattern, which is also referred to as 50% rod density, brings the reactor to or slightly beyond the point of criticality. From this point, the remaining fully inserted rods will be withdrawn in the order and in the increments specified by the operating swquence, until full power operation has been achieved. So long as the power level is below the low power set point, the rod movements specified in the sequence will be enforced by the RWM system.

b. Rod Group. Rod groups are the sequential subdivisions of an operating sequence. A rod group consists of a number of specified control rods (from one to a dozen or more) and a set of insert and withdraw position limits that apply to each rod in the group. The groups are numbered in the order in which they are to be followed when going up in power. For example, group 1 of an operating sequence contains the rods which are to be withdrawn first when the startup procedure is begun with all rods fully inserted. The insert limit for this group is, therefore, 0 (the fully inserted position), and since the general pattern followed by most sequences is to first withdraw fully about half the rods, the withdraw limit for group 1 will probably be 48, or the fully withdrawn position. When all the rods in group 1 have been withdrawn to the group 1 withdraw limit, the operator proceeds to group 2. Thus, at any point (group i) in the sequence, assuming the sequence has been strictly followed, all the rods in group 1 through i-1 should be at the withdraw limit for their respective groups, while all the rods in groups i+1 through the highest numbered group should be at the respective group insert limit. After the black/white pattern had been achieved (generally in group 4), the span between insert and withdraw limits for higher groups generally becomes considerably smaller, so that a given rod or set of rods may comprise more than one group. In this case, the withdraw limit for a rod in a given group will be the same as the insert limit for the next higher group in which the rod appears.

c. Notch Limits. All rods in groups higher than the group in which the black/white pattern is achieved, up to the group in which the power level exceeds the low power set point, have notch control restraints superimposed on the normal group limits. This means that in additon to remaining within the group limits, any rod contained in one of these notch control groups must also remain within one notch position of every other rod in the same group. If such a rod is moved so as to violate this restriction, a NOTCH ERROR light on the RWM operator's panel will be lit and all rod movement other than that required to correct the notch error will be blocked. Should a situation arise in which a violation of group limits is detected concurrent with notch errors, the notch errors must be corrected prior to correction of the group limit violation. Provision is made for printout on the alarm typer of the group numbers of all notch control groups (up to a miximum of six) currently having notch errors. Provision is also made for taking any notch control group out of service. This can be done from the RWM operator's panel by depressing the GROUP IN/OUT OF SER button, provided one of the rods in the group is currently selected. Removing a group from service has the effect of dropping that group out of the operating sequence. Selection of any rod in the out of service group will result in withdraw and insert blocks being applied. A group previously removed from service can be placed back in service by first selecting one of the rods in the group and again depressing the GROUP IN/OUT OF SER button.

d. Nominal and Alternate Group Limits. In addition to the nominal insert and withdraw limits for each rod group which are specified on the printed sequences provided for the operator's use, each rod group is assigned within RWM software a set of alternate insert and withdraw limits. All the alternate withdraw limits are defined as being one notch positon less than the corresponding nominal limit. A notch position is one of the even-numbered axial positions between 0 and 48 at which a rod can be stopped. To illustrate, assume that the nominal withdraw limit for a given rod group is specified as position 26. The alternate withdraw limit for this group will then be position 24. The same holds true for the alternate insert limits, with the exception of the alternate limits for groups having a nominal insert limit of 0. For these groups, the alternate insert limit is position 2. Assignment of these alternate limits is well within the RWM design specification, which allows for a tolerance of $\pm$ 2 notch positions on the nominal limits. Since the RWM program will consider a rod to be at the group limit when it is in either the nominal or alternate limit position, the addition of alternate limits materially reduces the changes that the program will generate unnecessary rod blocks due to failure of a rod position sensor at one of the group limit positions. As a further safeguard against rod position sensor failure, the RWM program will automatically read from drum a substitute rod position for any rod with bad scanned position data, provided that a substitute position for this rod has been previously stored on drum by operation of program OD-14.

e. Latched Group. The latched group is the highest numbered group within the operating sequence compatible at a given time with the existing distribution of control rod positions. As control rods are being moved to raise or lower the reactor power level. latching of the next higher or next lower group is done internally by the RWM program. The program will change down (latch the next lower group) when all the rods in the presently latched group have been inserted to the group insert limit as the reactor is coming down in power. The program will change up (latch the next higher group) when, with the reactor going up in power, all the rods in the currently latched group and in all lower groups, save two rods, have been withdrawn to their respective group withdraw limits. The number of currently latched group is displayed in the ROD GROUP windows on the RWM operator's panel. An evaluation of the current rod position distribution to determine the group that should be latched is performed by the RWM program at system initialization and ar various other times during normal program operation to ensure that the power group is latched at all times.

f. Low Power Set Point. The low power set point (LPSP) is the core average power level below which the RWM program is effective in forcing adherence to the operating sequence of rod withdrawals or insertions. When the core power level is above the LPSP, the RWM program does not impose any constraints sequence ceases to be enforced above the LPSP. Rod blocks due to hardware failure, however, are applied at all power levels. The low power set point is determined by a steam flow measurement, and is resettable by adjustment of this sensor. The LPSP is typically set at about 25% of rated core power.

g. Low Power Alarm Point. The low power alarm point (LPAP) is the core power level above which all RWM functions except hardware failure-initiated rod blocks are inoperative. The low power alarm point setting is based on reactor steam flow, and is adjustable by calibration of the steam flow sensor in the feedwater control system. A nominal value for the LPAP setting is 35% of rated core power; it is always set at some point higher than the LPSP setting. The AUTO lights on the RWM operator's panel is lit whenever the reactor is operating above the LPAP, indicating that the RWM functions are automatically bypassed.

h. Transition Zone. Transition zone (T.Z.) is the name given to the range of power levels above the low power set point but below the low power alarm point. When the reactor is operating in this range, the RWM does not enforce the operating sequence (although rod blocks due to hardware failure will still be applied), but the system alarms and displays, except for the WITHDRAW ERROR windows, are operative and are updated every five seconds.

i. Withdraw Error. A withdraw error can occur either when a rod contained in the currently latched group or any lower group is withdrawn past the withdraw limit for the group, or if a rod contained in a group higher than the one that is latched is withdrawn past the insert limit for the higher group. In most instances, these two actions amount to the same thing, since by withdrawal of a rod past a group withdraw limit, a higher group is thereby entered (assuming that there is, in fact, a higher group in which the rod is also contained). When a withdraw error occurs with the reactor operating below the LPSP, the X-Y coordinates of the rod responsible for the error are displayed in the WITHDRAW ERROR window on the operator's panel.

j. Inset Error. An insert error occurs when a rod contained in the currently latched group is inserted past the insert limit for this group, or if a rod contained in a group lower than the one that is latched is inserted past the withdraw limit for the lower group. The RWM operator's panel contains two digital display windows for identification of rods responsible for insert errors.

k. Withdraw Block. A withdraw block is imposed by the RWM whenever the program determines that a withdraw error has been made, and is also applied if, with three insert errors existing and an insert block having previously been applied, any rod other than one of the insert error rods is selected. In each case, the purpose of the block is to force correction of the withdraw or insert errors before allowing withdrawal of any other rods. Withdraw blocks are alarmed on the RWM operator's panel by a WITHDRAW BLOCK indicator light.

l. Insert Block. An insert block is applied by the RWM program when, with two insert errors having previously been made and left uncorrected, a rod is moved so as to cause a third insert error. An insert block is also applied in two other instances: when a withdraw error has been made and a withdraw block applied, and a rod other than the error rod is then selected; and also when, with the reactor coming down in power, a withdraw error is found to exist or the operating sequence is not latched when the power level reaches the LPSP. In this case, the LOW POWER light on the RWM operator's panel is turned on concurrently with application of the insert block. All insert blocks are alarmed on the operator's panel by an INSERT BLOCK indicator light.

m. Select Error. A select error occurs whenever, with the reactor operating below the LPSP, the operator selects a rod other than one contained in the currently latched rod group or one currently positioned so as to cause a withdraw or insert error. An alarm light on the RWM operator's panel is lit when a select error is made.

n. Rod Test Mode. This is a special mode of RWM operation, selectable by a pushbutton on the operator's panel, under which the RWM system will allow any one control rod unlimited movement, provided all other rods are fully inserted. If the ROD TEST pushbutton is pressed when more than one rod is withdrawn from the fully inserted position, the system will apply insert and withdraw blocks, and will display the second rod found withdrawn in the WITHDRAW ERROR windows. The withdrawn rod(s) must be inserted before the rod test request will be honored. When the request is honored, the ROD TEST SELECT light on the operator's panel is lit. The test mode is de-selected by pressing the ROD TEST pushbutton a second time; the ROD TEST SELECT light will then extinguish, indicating that the system has returned to its normal operational mode.

o. Manual and Auto Bypass. There are two ways in which the rod worth minimizer function can be bypassed. Removal of rod sequence restraints above the LPSP and removal of the RWM error alarms and displays above the LPAP have been previously described. This circumvention of RWM restraints due to reactor power level is referred to as auto byppass, and is indicated on the RWM operator's panel by an AUTO bypass indicatior light that is turned on whenever the power level is above the LPAP. In addition, the operator can manually defeat the RWM functions at any power level by turning a keylock switch on the operator's panel from NORMAL to BYPASS. This is known as manual bypass of the RWM. A MANUAL bypass light on the panel is turned on whenever this switch is in the BYPASS position.

E. COMPONENT DESCRIPTION (See figure 6)

1. The central component of the rod wirth minimizer is the process computer (GE PAC 4020) which performs reactor core calculations, provides the reactor operator with current core operating data which has been collected by plant instrumentation stors rod programs, and compares actual rod sequence with stored rod sequence programs.

a. Digital input scanner

1) Scans incoming data and transmits data to the computer in digital language upon command from the computer program.

2) Has the following inputs associated with the RWM

a) RPIS failure

b) Insert/withdraw permissive echos

c) Rod selected and driving signal for RPIS

d) Control rod identification signal from RPIS

e) Control rod position signal from RPIS

f) Rod drift signal from RPIS

g) Above LPAP/LPSP signal

h) RWM operable signal

i) Rod test request signal

j) Place group in/out service request signal

k) Print notch errors request signal

l) System diagnostic request signal.

b. The multiple output controller distributes program output from the process computer central processor to controls and indicators on the operator's consoles and RWM operator panel to the RWM output buffer, and to other components associated with the process computer but not with the RWM.

c. See the lesson plan on the process computer for more detail.

2. RWM output buffer

a. Receives central processor outputs via the multiple output controller.

b. Receives data and control inputs originating at the RWM operator's panel and the reactor power level signals from the feedwater control system.

c. Applies rod blocks or permissives to the control rod drive system as directed by the RWM program.

d. Mounted on panel 9-28.

3. RWM operator's panel (See figure 7)

a. Contains all operating controls and indicators for the RWM system.

b. Mounted on panel 9-5

c. For details of this panel see section F. Instrumentation

F. INSTRUMENTATION

1. RWM operator's panel controls and indicators and associated functions are listed below:

a. INSERT ERROR Digital Display Windows. These two four-digit displays are used to idintify control rods responsible for causing insert errors. The X coordinates of the error rod are displayed in the two leftmost positions of each display, and the Y coordinates are shown in the two rightmost positions. The rod which causes the first insert error encountered by the program is identified in the upper of the two INSERT ERROR displays. If a second inser error occurs before the first error has been corrected, the second error rod is identified in the lower display window. Each of the four positions in each window can display the numerals 0 through 9. If there are no insert errors, if the power level is above the LPAP, or if the RWM is bypassed, these windows are blanked.

b. WITHDRAW ERROR Digital Display Window. This four-digit display is used to identify a control rod responsible for a withdraw error. Each position can display the nemerals 0 through 9. The X coordinates of the error rod are shown in the two leftmost positions, and Y coordinates are shown in the two rightmost positions. The WITHDRAW ERROR display is blanked if there is no withdraw error, if the RWM is manually bypassed, or if the power level is above the LPSP.

c. ROD GROUP Digital Display Window. Thistwo -digit display is used to display the group number of the rod group that is currently latched. Each of the two positions can display the numeral 0 through 9. The window is blanked whenever the RWM is bypassed, when the power level is above the LPAP, or when no sequence, and consequently no rod group, is latched.

d. SELECT ERROR Indicator light. This indicator lights amber whenever a control rod is selected which is not contained in the currently latched rod group or which is not an error rod responsible for an existing rod block.

e. INSERT BLOCK Indicator Light. This indicator lights red whenever an insert block is applied by the RWM program.

f. WITHDRAW BLOCK Indicator Light. This indicator lights red whenever a withdraw block is applied by the program.

g. MANUAL Indicator Light. This indicator lights red when the RWM is manually bypassed; that is, whenever the keylock switch on the panel is in the BYPASS position.

h. SELECT BLOCK Indicator Light. This indicator lights red whenever a select block is applied by the RWM program. A select block is applied, together with insert and withdraw blocks, when the RWM is initialized, and the blocks remain until the program has determined whether a sequence is selected. All three blocks are also concurrently applied during a system diagnostic routine and whenever the RWM program is aborted due to hardware or software failure.

i. AUTO Indicator Light. This indicator lights red whenever the reactor power level is above the low power alarm point.

j. NORMAL - BYPASS Keylock Switch. This switch is used to manually bypass the RWM function. It is normally maintained in the NORMAL position, in which the key is removable. To bypass the RWM when the power level is below the LPAP, the key must be inserted and the switch turned to the BYPASS position. The MANUAL indicator light will then be lit and all error and alarm displays and indications will be blanked.

k. OUT OF SEQ - SYSTEM INITIALIZE Pushbutton Switch/Indicator. The SYSTEM INITIALIZER switch is depressed to initialize the RWM system. Initialization must be performed whenever the RWM has been taken off line, as occurs whenever the RWM program is aborted. Therefore, following any program abort, the SYSTEM INITIALIZE switch must be depressed before the program can again be run. The SYSTEM INITIALIZE portion of the window lights white while the switch is held down. The amber OUT OF SEQ light is turned on under program control whenever the LPAP is reached when coming down in power and it is found by the program that a withdraw error (or errors) exist, that three or more insert errors exist, or that one or more notch errors exist. The purpose of the light is to warn the operator that there is incompatibility between the operating sequence and the existing rod positon distribution and that failure to correct this condition will cause an insert block to be applied when the LPSP is reached.

l. PRINT NOTCH ERR Pushbutton. This switch is used to request a printout an the alarm typer listing the numbers of all rod groups, up to a maximum of six, in which notch errors exist. This request can be made at any time, as often as desired. The printout has the following format (assume that only groups 5 and 16 have notch errors).

Notch Error Groups 5 16 0 0 0 0.

m. NOTCH ERROR Indicator Light. This indicator lights amber whenever a rod in a notch control group is moved so as to create a notch error; that is, to a position at which it is not within one notch of every other rod in the group. Movement of all other rods will then be blocked until the notch error is corrected, at which time the NOTCH ERROR light will be extingusihed.

n. GROUP IN/OUT OF SER - GROUP OUT OF SER Pushbutton Switch/Indicator. The GROUP IN/OUT OF SER switch is used to take a notch control group out of service, or to return to service a group previously removed from service. A group can be removed from service only if it is a group in which notch restraints are imposed, if there are no notch errors in the group, and if a rod in that group is presently selected. If these conditions are met, the group will be taken out of service when the GROUP IN/OUT OF SER switch is pressed. The GROUP OUT OF SER light will be lit, and will be lit any time thereafter when any rod in the out of service group is selected. To return the group to service, a rod in the group must first be selected, and the GROUP IN/OUT OF SER switch again pressed. The GROUP OUR OF SER light will then be extinguished, indicating that the group has been returned to service. Depending on the positions of the rods in the returned group relative to the group insert and withdraw limits, it is possible that insert or withdraw errors may occur when the group is returned to service. If this is the case, the errors must be corrected before any other rod movements will be permitted.

o. ROD TEST - SELECT Pushbutton Switch/Indicator. The ROD TEST switch is used to place the RWM system in the rod test mode. In order for this to be done, no more than one rod in the entire core can be withdrawn from the fully inserted position. If this condition holds, the SELECT indicator lights white when the ROD TEST switch is pressed, indicating that the rod test request has been honored and that the system is now in the rod test mode. So long as this mode remains in force, any one rod may be selected and moved to any position, provided that all the other rods in the core remain fully inserted. The rod test mode can be terminated by again pressing the ROD TEST switch, at which time the SELECT indicator will be turned off and the RWM system will be returned to its normal operational mode.

p. SYSTEM DIAGNOSTIC Switch/Indicator. This switch can be pressed at any time after the system has been initialized to request that the system diagnostic routine be performed. The RWM program will thereupon be initiated and will perform the routine, which consists of applying and then removing in sequence the insert and withdraw blocks. The operator can verify the operability of the ord block circuits by observing that the INSERT BLOCK and WITHDRAW BLOCK alarm lights come on and then go off as the blocks are applied and removed. The SYSTEM DIAGNOSTIC indicator lights white when the switch is depressed. It will remain on, and the diagnostic routine will be repeated over and over until the switch is depressed a second time. This halts the routine and extinguishes the indicator light.

q. RWM - COMP - PROGR - BUFF Pushbutton Switch/Indicator. The four segments of this indicator are used to alarm various hardware and software failures within the RWM system. The pushbutton switch is used both to verify that the indicator lights are operative and to reset the lamp driver circuits for these indicators in the output buffer. The PROGR quadrant of the indicator is lit whenever the RWM program is inoperative; i.e., whenever the program has been aborted and has not be reinitialized or when the RWM is manually bypassed. The COMP quadrant is lit whenever a computer stall or a bit parity check error occurs. The RWM quadrant is lit concurrently with either the PROGR or COMP quadrants. The BUFF quadrant is lit whenever the three computer inputs to the majority voter circuits for any one of the select, insert, or withdraw permissive functions are not all in the same state. When the pushbutton is depressed, all four of the indicator quadrants light up for as long as the pushbutton is held down. When the pushbutton is released, the lamp driver circuits for these indicators in the output buffer are reset and, provided none of the failure conditions just described are still present, all four of the indicator lights are extinguished.

G. OPERATIONAL SUMMARY

1. RWM Startup

   a. Ensure the process computer is operating

   b. Load RWM Sequence A or B into the computer

   c. Place the NORMAL - BYPASS switch in the NORMAL position

   d. Press the system initialize switch to bring the RWM on the line.

2. Operation with two insert errors

   a. When withdrawing rods at power levels below the LPSP it can become necessary or desirable to leave one or two rods at positions lower than their withdraw limits and enter the next higher group.

   b. When the group is reached that contains the one or two rods and the positions they are to be left at, withdraw the rod or rods to their respective position (It is assumed that the group in question is below the 50% rod density point.)

   c. Withdraw all other rods in the group to the withdraw limit position for the group.

d. Select any rod in the next higher group. The program will then change up to this group, the ROD GROUP display will show the higher group number, and the one or two rods remaining inserted in the lower group will be identifed as insert errors.

e. The withdrawal sequence can now proceed normally, as long as no more than two insert errors are allowed to occur.

Notes: 1) If the group that is to contain the insert errors is a notch control group (i.e. between the 50% rod density point and the LPSP), it may be necessary to leave all the rods in the group within one notch of one another and remove the entire group from service.

2) There is no parallel to this procedure to use when coming down in power, since no withdraw errors will be tolerated by the system.

3. Latching and relatching

a. At system initialization and at various other times during RWM operation, the system evaluates all control rod positions for purposes of updating the ROD GROUP, WITHDRAW ERROR, and INSERT ERROR displays and for determining whether any rod blocks, alarms, or error indications need to be generated.

b. This is called latching or relatching

c. When it occurs, the latched group will be displayed in the ROD GROUP windows. It will be the highest group having less than three insert errors in the groups below it and having at least one rod withdrawn past its insert limit.

d. Normal latch

1) If all rods are fully inserted at the time of RWM system initialization, the latched and displayed rod group will be group 1.

2) When a rod in group 1 is selected, permissives will be applied and no alarms will occur.

3) As long as the sequence is followed, no alarms or blocks will be generated as rods are withdrawn.

e. Relatch at an intermediate power level

1) If system initialization or relatch occurs at an intermediate point in the withdraw sequence, where rods have been moved out of sequence, controlled recovery can still be affected as illustrated in the following example:

   Note: Refer to the rod sequence given as figure 4 and the rod groups given as figure 5.

2) Assume the following rod position distribution:

   a) All rods in groups 1 through 3 are fully withdrawn, except for one rod in each group - 22-51 in group 1, 46-55 in group 2, and 18-03 in group 3 - all fully inserted.

   b) All rods in groups 4 through 10 are fully inserted to position 0 except for rod 34-27 in group 4 which is fully withdrawn.

3) At initialization or relatch, the ROD GROUP display will show group 3 as the latched group.

   a) Rods 22-51 in group 1 and 46-55 in group 2 will be displayed as insert errors.

   b) Rod 34-27 in group 4 will be displayed as a withdraw error.

   c) The withdraw error will cause the OUT OF SEQ alarm light to be lit.

   d) The only rods that are allowed to move are the two insert error rods (22-51 and 46-55), the withdraw error rod (34-27), and all rods in the latched group (group 3)

4) One way to correct the out of sequence condition is to insert the withdraw error rod (34-27) to position 0

   a) This removes the withdraw error, leaves group 3 as the latched group, and leaves rods 22-51 and 46-55 displayed as insert errors.

   b) Operation can continue as per 6.2

5) Another way to correct the out of sequence condition is to withdraw either of the two insert error rods (22-51 or 46-55) or rod 18-03 in group 3 to position 48.

a) The program then changes up and latches group 4.

b) The two rods left at position 0 will be displayed as insert errors.

c) Operation can continue as per 6.2

4. Program aborts

a. The RWM program can be aborted for a variety of reasons listed below.

b. When an abort occurs, the RWM is taken off the line by the turn-off subroutine, withdraw and insert blocks are applied, and the system must be re-initialized before the program can be executed again.

c. Program aborts are alarmed at the operator's panel by the RWM and PROGR INOP/RESET lights.

d. Reason for RWM program aborts.

1) RPIS Failure. When the program is first initiated, it performs a series of tests to verify hardware and software operability and to check the validity of rod selection input data. One of the hardware tests made is for operability of the rod position information system (RPIS), from which the RWM receives all its rod identification and rod position inputs. If the test shows that the RPIS is failed, the program is aborted and the following message is typed on the alarm typer: "RWM - RPIS failed".

2) Invalid Rod Select Data: As a test of the validity of the rod selection input data, the program examines two separate sources of this information. The two inputs are designated as "rod selected" and "rod selected & driving". If these two inputs are contradictory (specifically, if the "rod selected" input shows no rod selected while the "rod selected & driving" input indicates that a rod has been selected, the program aborts and the following message appears on the alarm typer: "RWM - Rod selected & driving, rod not selected."

3) Invalid Rod I.D. If a rod is in fact selected, the program checks the identification of the selected rod to ensure that it is valid; that is, that the rod identification input defines an actual control rod. If it does not, the program aborts and the following message appears on the alarm typer: "RWM - Invalid rod identification."

4) RWM Inoperable. After checking for the presence and validity of required inputs, the program then interrogates and internal digital input to determine if the RWM system is operable. The system will be considered operable provided it is not bypassed and provided either that system initialization has just occured or that the RWM was already on line at program initiation. If these conditions are not satisfied, the program is aborted and the following message is typed on the alarm typer: "RWM - RWM operable input logic 0."

5) Sequence Not Loaded. If the system has just been initialized to start the program, a test is made to determine if an operating sequence is loaded. If not, the program aborts after typing the following message on the alarm typer: "RWM - Load sequence before starting."

6) Rod Scan Failure. When the system has just been initialized to start the program, a scan of all the control rod positions is called for just after the RWM is placed on line. A control rod scan is also demanded when the LPSP is reached while coming down in power, to determine whether an insert block should be applied. If a scan called for by the program cannot be completed, the program aborts and types the following message on the alarm typer: :RWM - Control rod scan failed."

7) Block or Permissive Failure. Following the initial checks of inputs and system operability and, if required, the system initialization procedure, the program checks to see if the rod blocks and permissives are as last ordered. If they are not, it attempts to put them in the proper order. If unsuccessful after three trys, the program aborts and issues one of four failure messages on the alarm typer identifying the block or permissive that could not be put in its proper state. The message format is as follows: "RWM - Failed applying (withdraw or insert) (block or permissive)

8) Power Level Data Bad. The program initiates a five-second delay cycle whenever the reactor power level crosses either the low power set point or the low power alarm point. Both the LPSP and LPAP delay cycle indicators are interrogated on each operation of the program to determine where the power level is and whether it is going up or coming down. If contradictory information is obtained form the LPSP or LPAP indicators (i.e.. if the power level is indicated as being simulaneously below the LPSP and above the LPAP), the program aborts and the following message is typed on the alarm typer: "RWM - LPSP logic 0 and LPAP logic 1."

9) More than Three Insert Errors. When the program checks the position of the selected rod against the insert limit for the latched group, it tabulates the number of insert errors to determine whether an insert block or insert permissive should be applied. If the insert error count totals more than three, the program aborts, since that is a condition that should never occur if the system is operating properly. The following abort message is typed on the alarm typer: "RWM - More than three insert errors."

10) More Than One Withdraw Error. When comparing the selected rod's position with the latched group withdraw limit, the program tests to determine if any withdraw errors exist. If the test indicates more than one error, the program aborts and the following message is typed on the alarm typer: "RWM - More than one withdraw error."

11) Computer Multiple Output Controller Failure. The BCD input to the RWM operator's panel required to provide the WITHDRAW ERROR, INSERT ERROR, and ROD GROUP displays are supplied from the computer multiple output controller, which is also known as the multiple output distributor (M.O.D.). In the event of an overload or other hardware failure in this unit, the RWM program is aborted and the following message appears on the alarm typer: "RWM - M.O.D. failed."

12) Segment Transfer Failure. In order to reduce the core space that must be allociated for its operation, the RWM program, like a number of other large process computer programs, is organized into separate segments. There are two segments of the RWM program, only one of which is occupying and being executed in core at any given time. When Segment One has been completed, one of serveral entry points into Segment Two is designated, depending on current system status, and a subroutine is employed to transfer Segment Two from drum into the core space presently occupied by Segment One . A similar transfer of Segment One back into core may be called at the completion of Segment Two. Should either of these transfers fail to be accomplished, the RWM program is aborted and the following message is typed on the alarm typer: "RWM segment transfer failure."

[illegible]. RELATIONSHIPS WITH OTHER SYSTEMS

1. The RWM is directly related to the process computer.

2. Rod position and selected rod comes from the rod position indication system.

3. Rod blocks are applied to the reactor manual control system.

4. A power level signal based on steam flow comes from the feedwater control system.

5. The rod sequence control system is considered a backup for the RWM.

I. TECHNICAL SPECIFICATIONS

1. Whenever the reactor is in the startup or run modes below 20% rated power, the RWM shall be operable or a second licensed operator shall verify that the operator at the reactor console is following the control rod program.

   Note: If this specification cannot be met the reactor shall not be started, or if the reactor is in the run or startup modes at less than 20% rated power, it shall be brought to a shutdown condition immediately.

2. The capability of the RWM shall be verified by the following checks:

   a. The correctness of the control rod withdrawal sequence input to the process computer shall be verified before reactor startup or shutdown.

   b. The RWM computer on line diagnostic test shall be successfully performed.

   c. Prior to startup, proper annunciation of the selection error of at least one out-of-sequence control rod shall be verified.

   d. Prior to startup, the rod block function of the RWM shall be verified by moving an out-of-sequence control rod.

   e. Prior to obtaining 20% rated power during rod insertion at shutdown, verify the latching of the proper rod group and proper annunciation after insert errors.

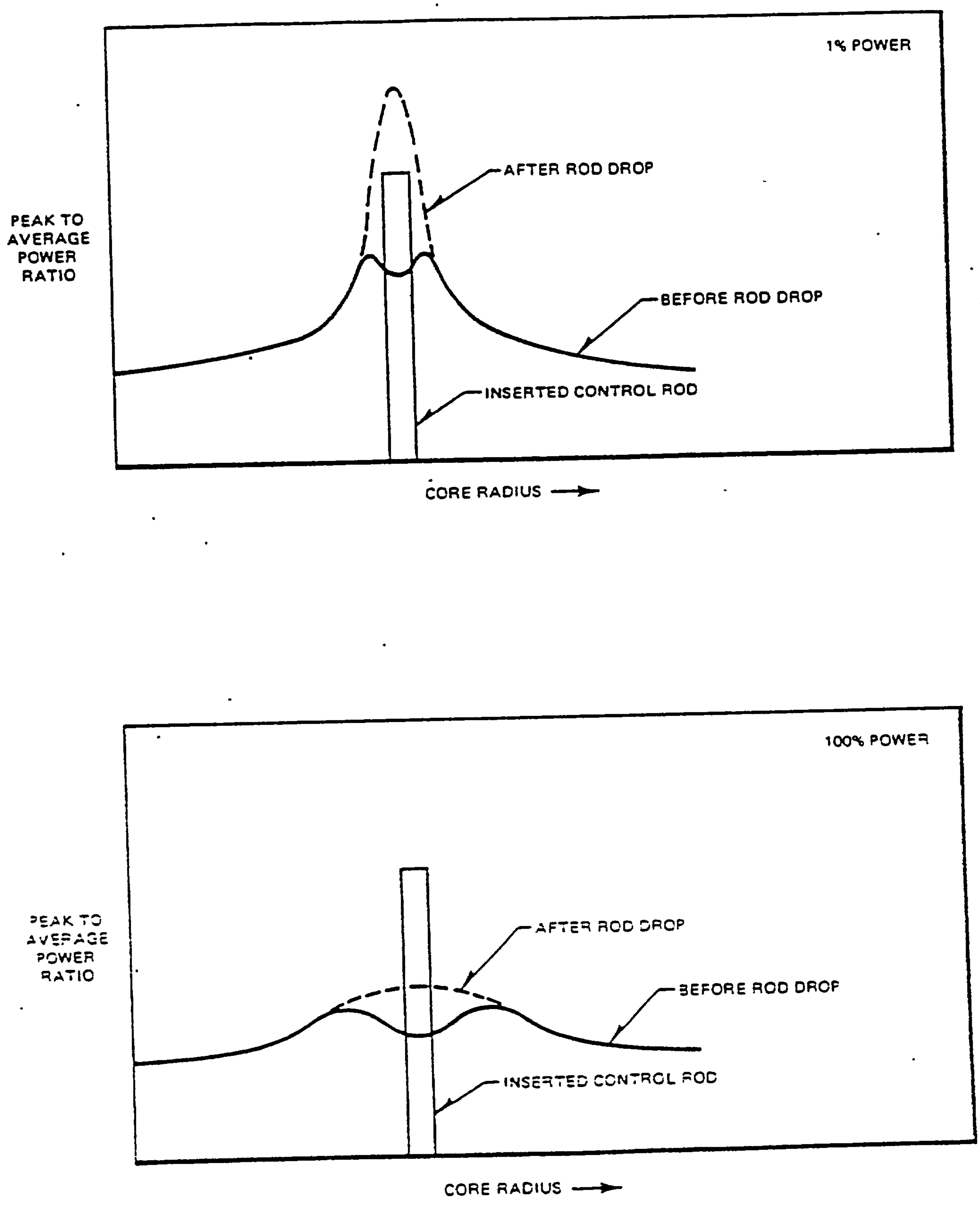

Figure 1 POWER LEVEL EFFECT ON CONTROL ROD WORTH

Revision ____________________

Date ____________________

BWR SYSTEMS

LESSON PLAN

A. REACTOR PROTECTION SYSTEM (RPS)

B. REFERENCES

1. BWR Systems Manual - Chapther 7.1

2. GEK 32556 - Reactor Protection System, Brown's Ferry

3. GEK 779 - Instruction Manuals for Vendor Supplied Equipment, Vol. 10 Brown's Ferry

4. Brown's Ferry Procedures

   a. Operating Instructions - OI 99

   b. Surveillance Instruction - SI 4.1.A ⟹ 16 and 4.1.B1 ⟶ 15

5. Brown's Ferry Prints

   a. Mechanical Logic - 47W611-99

   b. Mechanical Control - 47W-610-1,2,3,4,7,54,90

6. Technical Specification, Brown's Ferry Nuclear Plant

7. Final Safety Anaylsis Report, Brown's Ferry Nuclear Plant

8. Card File - 7.1

C. OBJECTIVES

1. Purpose of the system

2. Components of the system

3. Significant RPS instrumentation. interlocks and alarms

4. Scrams and reason for each

5. How a trip causes control rod insertion

6. Reset of a scram

7. Design basis of the system

8. Review of electrical schematic reading and interpretation

9. Technical Specifications of the system

D. GENERAL DESCRIPTION

1. Purpose

   a. Monitor critical parameters during all modes of reactor operation to protect against conditions that could threaten the fuel barriers and reactor coolant pressure boundary.

   b. Reactor Protection System (RPS) protects:

      1) Against excessive thermal heat flux that threatens to perforate the fuel cladding or melt the fuel.

      2) Against excessive reactor pressure that threatens to rupture the reactor coolant boundary.

      3) To minimize the energy which must be absorbed following a loss of coolant accident, and prevent criticality.

2. System Description

   a. A system of sensors monitoring the critical parameters which control fast response, high reliability relays.

   b. The relays, if tripped, will cause a reactor scram.

   c. Definition of Reactor Scram

      1) Rapid insertion of all operable control rods by:

         a) De-energization of all scram pilot solenoid valves.

         b) Energization of the backup scram valves.

         c) Isolation of the scram discharge volume.

3. Consists of :

   a. Two motor-generator power supplies.

   b. Sensors, relays and bypass circuitry of the logic channels.

      1) There are two independent, functionally identical relay logic channels. (RPS Channel A & B.)

2) Each channel is divided into two identical subchannels for reduncancy and reliability.

3) Four subchannels constitute the one-out-of-two twice scram logic used throughout the system.

4) The logic is normally energized and is fail-safe (de-energizes to trip).

c. Switches, contacts and valves that cause rapid insertion of all control rods.

E. COMPONENT DESCRIPTION

1. Power Supply (Figure 1)

a. The RPS consists of two independent trip systems powered by indepedent electrical buses.

1) Normal power to RPS buses A and B is supplied by two motor-generator sets.

a) Motor

(1) 25 Hp.

(2) 48V AC

(3) 3 Phase

b) Generator

(1) 120V AC

(2) Single Phase

(3) 60 hertz

(4) 18.75 kVA, 15 kW, 0.8% power factor

c) Motor Generator-Flywheel Specifications

(1) Steady-State; voltage regulation- = 2% 360Hz, frequency change- 1% (No load to full load)

(2) For a 50% step load change, voltage and frequency- ± 15%, recovery to steady-state within 1 second.

(3) With a 3 second voltage interruption; voltage and frequency will not drop more than 5%, recovery within 5 seconds.

d) RPS MG Sets A and B supply power to RPS buses B and A respectively.

(1) Each RPS bus and associated circuitry is referred to as a scram channel.

(2) Each cram channel is futher divided into two sub-channels (i.e., A-1, A-2, B-1, B-2).

e) Power from buses A and B is also used to normally energize the S.39A and S.39B scram pilot solenoid valves, on each of the Hydraulic Control Units, respectively.

2) Reserve Power to RPS Bus

a) From 480V Shutdown Board 1B via the Unit Preffered Transformer.

b) Interlocked so that both RPS buses connot be simutaneously fed from reserve power.

c) Interlocked to prevent paralleling RPS MG set with reserve power

2. <u>Scram Valves (Figure 2)</u>

a. Purpose:

To provide a path for scram water flow when air pressure to them is relieved.

b. One pair of valves per Hydraulic Control Unit (185 units total). Both valves are normally closed.

1) Scram Outlet Valve F-39B)

a) Vents CRD "over piston" area to scram discharge volume.

b) Open faster than inlet valve on scram.

(1) Stronger spring

(2) Shorter run of air piping, hence faster air pressure bleed off.

2) Scram inlet valve (F-39A):

Applies accumulator pressure to the CRD "under piston" area.

c. Valve Construction

1) Air-to-close.

2) Spring-to-open.

3) Controlled by a solenoid operated pilot valve. (Scram pilot solenoid valve)

4) Air pressure to the scram valves is from the 100 psig Control air system reduced to 75 psig.

3. Scram Pilot Solenoid Valves (Figure 2)

a. Purpose:

1) To direct air pressure to the scram valves, holding the scram valves shut.

2) By repositioning, when tripped, to rapidly bleed air pressure from the scram valves.

b. Functional Description

1) Two valves per pair of scram valves (Both valves must de-energize to vent air from the scram valves on a particular Hydraulic Control Unit).

2) The valves are divided into two sets.

a) The S.39A valves are energized by RPS Bus A (a set).

b) The S.39B valves are energized by RPS Bus B (a set).

c) The Hydraulic Control Units (HCU's) are physically separated in the Reactor Building, half on either side of the drywell.

d) Each set is divided into four groups of valves (Group I, II. III. IV).

(1) Minimizes current requirements through contacts and relays, hence increases component life.

(2) Each group contains about 1/4 of the HCU's.

e) Subchannel Trips

(1) A trip in RPS subchannel A-1 or A-2 will de-energize the S-39A valves in all four groups.

(2) A trip in RPS subchannel B-1 or B-2 will de-energize the S-39B valves in all four groups.

c. Construction

1) Three-way valves

2) 120V AC, solenoid operated

4. <u>Scram Discharge Volume (Figure 2)</u>

a. Purpose:

To provide a volume of piping sized to receive scram discharge water from the control rod drive "over piston" area as a result of a reactor scram.

b. Construction

1) Parallel 6" piping, above the Hydraulic Control Units, connected by a common header at one end.

c. Instrument Volume

1) Purpose:

As the low point in the systme it provides the means to detect the pressure of any water in the scram discharge volume.

2) Construction

a) A 12" diameter vertical tank

b) Uses float switches for alarms, rod block and acram functions.

3) Instrumentation

a) Alarm - 3 gallons

b) Rod Out Block - 25 gallons

c) Scram - 50 gallons

5. <u>Scram Discharge Volume Vent and Drain Valves (Figure 2)</u>

a. Purpose:

To isolate the scram discharge volume upon a scram to limit leakage of reactor water past the CRD seals following a scram.

b. Quantity

1) Two vent valves, one for the scram discharge volume above the east Hydraulic Control Units; one above the west.

2) One drain valve off the scram discharge instrument volume.

c. Construction

1) Air-to-open

2) Spring-to-close

3) Normally held open by Control air, reduced to 75 psig through the two solenoid operated pilot valves.

a) A 3-way, 120V AC solenoid valve

b) One valve (S-37A) is normally energized by RPS Bus A; the other (S-37B) by RPS Bus B.

c) Both pilots de-energize on a scram, porting air from the vent and drain valves which close.

4) Disc. Vol. Isol. Test; Test Switch

a) Purpose:

To provide a means of isolating the scram discharge volume to permit leakage rate testing of the scram discharge valves.

b) Design

Switch is located on Panel 9-5 apron.

c) Functional Description:

(1) A solenoid operated, 3-way, pilot valve (S-36).

(2) The valve is between the content air line and the scram discharge instrument volume solenoid pilot valves.

(3) Normally de-energized; supplied by 120V AC from the instrument and control bus A.

(4) Going to isolate with the test switch energizes the test valve (S-36), blocks air to and vents air from the scram discharge volume vent and drain valves which then close.

6. <u>Backup Scram Valves (Figure 2)</u>

a. Purpose:

To provide a redundant means of bleeding air from the scram valves as a result of a scram signal.

b. Functional Description:

1) Two pair of valves located near the Hydraulic Control Units.

2) The valves are in the control air system between the air main and the scram valves air supply header.

3) On a scram, the valves block air supply to the header and vent the header to atmosphere.

4) Comparative scram times:

a) Normal - 90% control rod travel occurs by ~2.5 seconds typically; ~5.0 seconds maximum.

b) Backup scram valves only - 90% control rod travel, ~15 seconds.

c. Construction

1) Four, 3-way, 250V DC solenoid valves, arranged in two redundant pairs.

2) Normally de-energized

3) Supplied from the 250V DC Reactor MOV Boards A and B.

4) RPS Channels A and B must both trip (scram) to close contacts to energize each valve.

Note: Energizing any valve will cause a scram.

5) Downstream Check Valves

a) Ensures that a failure or blockage of the downstream valve (F-35B or F-70B) will not impair the capility of the upstream valve to scram the reactor.

b) The only failure of the downstream valve that would present problems is one that blocks all ports.

7. Separation of Components

a. Redundant Trip Subchannels (sensors, wiring, transmitter, amplifiers, etc.) are:

1) Electrically

2) Mechanically

3) Physically

independent so that they are unlikely to be disabled by a common cause except for electrical power failure.

b. The two trip channels are physically separated from each other and from other equipment to minimize the proability of interactions that might increase the possibility of false scrams or failure to scram.

c. Each trip sensor, relay, subchannel and channel is clearly identified to reduce the possibility of maintenance personnel (or others) causing inadvertent trips or undesired operations.

F. RPS SENSORS AND LOGIC

Note: The following discussion is to be carried out in order to assure that students can interpret schematic diagrams. Figure 3 through 7 are to be used to assist students in understanding the schematic diagrams. Electrical schematics are shown de-energized. Relay numbers are from Reference 2.

1. One-Out-Of-Two Twice Logic

a. Minimum inputs to the RPS are arranged in 1-out-of-2 twice coincident (occuring at the same time or place) trip logic.

b. An example of this is the reactor vessel high pressure scram (1055 psig).

1) There are four (4) pressure switches in the vessel high pressure scram logic.

   a) On figure 7

      (1) Pressure switches PS3-22 A and B tap the vessel through the instrument penetration on one side of the vessel.

      (2) PS-3-22 C and D tap the vessel at ∼180°.

2) On figure 3

   a) High pressure, as sensed by PS3-22A through D, opens contacts in the Channel A & B scram sensor relays.

   b) PS-3-22A & C from opposite sides of the vessel, de-energize relay 5A-K5 A & C respectively. (Channel A scram sensor Relays)

   c) PS3-22 B & D de-energize relays 5A-K5 B & D respectively. (Channel B scram sensor relays not shown).

   d) De-energize relays 5A-K5 A & C open redundant contacts in the Channel A scram relay logic. (The second contact from the same relay is provided to increase system reliability.)

   e) 5A-K5 B & D open redundant contacts in Channel B not shown.

   f) 5A-K5A de-energizes (drops out) 5A-K14 A & E.

   g) 5A-K5C de-energizes 5A-K14C & G.

   h) Channels A scram pilot solenoid valves (S-39A, figure 4)

   i) De-energized 5A-K14A or C will de-energize the solenoids for groups I & IV of Channel A (the S-39A valves in those two groups).

   j) De-energized 5A-K14E or G will de-energize the solenoids for groups II & III.

3) Half-Scram (Example)

   a) If PS3-22A senses reactor high pressure (1005 psig), by following the previous relay logic:

(1) 5A-K5A drops out (de-energizes).

(2) Then 5A-K14A & E drop out.

(3) The S-39A scram pilot solenoid valves - Group I, II, III and IV de-energize.

b) This is a half-scram and results from one (in this case) or both sensors in only Channel A, or Channel B, reaching its trip point. (Note that the S-39B scram pilot solenoid valves are holding air to the scram inlet and outlet valves and S-37B on the Instrument Volume vent and drain vales - see figure 2 - so no scram occurs.)

6) Scram

a) Assume that Channel A is tripped as above.

b) By the same relay logic, but in the B Channel, a half-scram can be realized.

c) If PS3-22D was tripped, then;

(1) 5A-K5D drops out (de-energizes).

(2) 5A-K14 D & H drop out.

(3) The four groups of S039B valves (scram pilot solenoids de-energize producing a half-scram.

(4) The half-scram results from one or both sensors in only Channel B, or Channel A, reaching its trip point.

d) When both RPS Channel A & B are tripped, all of the scram pilot solenoids are de-energized and the control rods are rapidly inserted into the core.

e) Thus a reactor scram occurs from a minimum of 1 or 2 tripped sensors in both channels, hence the meaning of 1-out-of2 twice logic.

2. Reactor Scram Signals and Arrangement

a. Subchannel Test Switch (Figure 3)

1) Purpose

Allows for testing each subchannel trip functions.

2) Four, one per subchannel

3) Keylocked, two position - Normal and Trip

4) "Trip" de-energizes that channel's 180 relays producing a half-scram.

b. <u>Turbine Stop Valves, 10% Closure</u>

1) Purpose:

To anticipate the pressure, neutron flux, and fuel cladding surface heat flux increase caused by the rapid closure of the turbine stop valves.

2) Design

a) Each of the four turbine stop valves is equipped with position switches.

b) These switches will provide a valve closed signal to the RPS logic.

(1) Set at ≤ 90% of full open.

3) Functional Description (Figure 6)

a) The position switch contacts are arranged so that any two stop valves can be closed causing no more than a single channel (RPS Channel A or B) trip - a half-scram.

b) Closure of any combination of three stop valves will cause a scram in all cases.

4) Example of Two Stop Valve Closure

a) Close stop valves 4 and 3.

b) In the RPS Channel:

(1) 5A-K14 C & G drop out, which

(2) De-energizes the S-39A scram pilot solenoid valves - a half-scram.

c) In the B RPS Channel:

(1) The 5A-K14 relays remain energized because:

(a) A parallel path is still closed around the contacts opened when the 3 & 4 stop valves are < 90% open.

d) From the logic it can be determined that: (Figure 6)

(1) Closing one valve does not cause even a half-scram.

(2) Closing 1 and 4 or 2 and 3 at the same time does not yield even a half-scram.

(3) Closing any other combination of two valves will cause a half-scram.

(4) Any combination of three or more valves closed (<90% Full Open) will cause a reactor scram.

6) Bypassed when power is <30% as sensed by turbine **first** stage pressure.

c. <u>Generator-Load Reject Scram</u>

1) Purpose:

To anticipate the rapid increase in pressure and neutron flux resulting from fast closure of the turbine control valves due to a load rejection.

2) Definition of load reject:

Greater than 40% mismatch between generator stator amps and turbine crossover pressure.

3) Design

a) A load reject signal will energize the fast acting solenoid valves on the control valve actuators, which removes hydraulic trip fluid pressure.

b) Trip signal comes from pressure switches on the fast acting trip control (FASTC) supply to the control valve disc dumps (Refer to EHC Hydraulics) Loss of this pressure will cause a rapid closure of the control valves.

c) Circuitry is desinged such that the pressure switch on either control valve 1 <u>or</u> 3 will trip (de-energize) RPS Channel A.

d) Either control valve 2 <u>or</u> 4 will trip RPS Channel B.

4) These switches will also provide a scram signal on loss of hydraulic trip fluid pressure when a load reject signal is not present - loss of hydraulic fluid pressure can result in a fast closure of the control valves.

5) Scram Bypass

This scram is bypassed when power is <30% as measured by turbine first stage pressure.

d. Scram Discharge Volume High Level, 50 Gallons

1) Purpose:

To initiate a scram while adequate volume is available to receive scram discharge water to assure that all operable drives will fully insert.

2) Design

a) Four independent, non-indicating float switches are provided on the scram discharge instrument volume. (Figure 7)

b) Two float switches from opposite legs of the instrument volume provide the 1-out-of-2 logic for the RPS channels.

3) Functional Description

a) LS 85-45 A or C are capable of tripping Channel A.

b) LS 85-45 B or D will trip Channel B.

4) Scram Bypass (Figure 3)

a) Must be able to bypass this scram, as it is received following all other scrams due to water from the control rod drives, to allow for resetting a scram. (Scram reset is discussed later.)

b) A two position, keylock switch on Panel 9-5

(1) Normal and Bypass

c) The mode switch must be in Shutdown or Refuel for bypass capabilities.

- Note -

Going to Startup/Hot Standby position with a high level in the instrument volume will cause a scram regardless of Bypass switch position.

f. <u>Condenser Low Vacuum, 23" Hg</u>

1) Purpose

a) To perform as a backup scram to the turbine stop valve closure scram.

b) Anticipates stop valve closure (Turbine Trip) on loss of vacuum (19"Hg) and subsequent scram.

(1) The stop valve closure scram function alone is adequate to prevent the clad safety limit from being exceeded.

(2) This scram occurs before the stop valves close, thus the resulting transient is less severe.

c) Anticipates loss of the condenser as a heat sink.

2) Design

a) Four vacuum switches to monitor condenser vacuum.

b) One switch each for condenser sections B and C.

c) Two switches for Section A.

3) Functional Description (Figure 7)

a) Channel A auxiliary trip relays are de-energized by switches on section A & B.

b) Channel B is controlled by the other switch on the A condenser section and the Section C switch.

c) Logic is 1-out-of-2 twice.

4) Scram Bypass: (Figure 3)

This scram is bypassed when reactor pressure is <1055 psig and mode switch is <u>not</u> in RUN.

g. <u>Main Steam Isolation Valves Closure, <90% Full Open</u>

1) Purpose:

To anticipate the pressure and flux transients which occur during normal or inadvertent isolation valve closure.

2) Design

a) The scram logic is identical to that for turbine stop valve closure.

3) Functional Description (Figures 6 & 7)

a) Main steam line inboard and outboard isolation valve position switch contacts are in series in the subchannel logic.

(1) The concern here is isolation of steam lines, not the total number of valves shut.

b) As with turbine stop valves, a maximum of two steam lines may be isolated (<90% full open on MS IVs) without scramming the reactor.

(1) Isolating one steam line does not cause even a half-scram.

(2) Isolating steam lines A and D or B and C does not cause even a half-scram.

(3) Isolating any other combination of two main steam lines will cause a half-scram.

(4) Isolating any combination of three main steam lines will cause a reactor scram.

- Note -

At high power levels it is possible to cause a scram by fully closing an MS IV. The scram is caused by high steam flow sensed in the other steam line flow restrictors which causes a Group I isolation. When the MS IVs go shut on the isolation the reactor scrams.

4) Scram Bypass:

This scram is bypassed when reactor pressure is <1055 psig and mode switch is not in Run.

h. High Drywell Pressure. -2 psig

1) Purpose:

Two psig indicates a leak in the primary system within the drywell. The scram limits the amount of energy and pressure transmitted to the drywell during a design basis accident. and prevent recriticality when the core is reflooded.

2) Design:

Signal comes from four independent pressure switches.

3) Functional Description (Figures 3 & 7)

Trip logic is the straight forward 1-out-of-2 twice.

4) Scram Bypass:

There is no bypass of this scram.

i. Reactor High Pressure, 1055 psig

1) Purpose:

To serve as a backup scram to the high neutron flux scram to limit vessel pressure to a value below the reactor vessel pressure safety limit.

2) Design:

Previously discussed under F.1.b.

3) Functional Description:

Previously discussed under F.1.b.

4) Scram Bypass:

There is no bypass of this scram.

j. Reactor Low Water Level, + 10"

1) Purpose:

Prevents power operation at water levels lower than those assumed in the safety analysis. Low water level indicates that the reactor core is in danger of having inadequated cooling.

2) Design:

Signal is from four (4) level indicating switches.

3) Functional Description (Figure 3 & 7)

a) One switch from each sensing leg controls a subchannel relay.

b) The logic is 1-out-of-2 twice.

k. Main Steam Line High Radiation, 3 Times Normal

1) Purpose:

Increased radiation level in the steam line tunnel above that due to the normal nitrogen and oxygen radioactivity (N^{13}, N^{16}, O^{19}), is indication of fuel failure. This scram reduces the source of such radiation.

2) Design

a) Four logarithmic radiation monitors are used.

b) Installed as a cluster.

(1) Approximately equidistant from all steam lines.

(2) Each detector is exposed to approximately the same total radiation level from all four steam lines.

3) Functional Description (Figures 3 & 7)

a) Logic is 1-out-of-2 twice.

4) Scram Bypass:

There is no bypass of this scram.

l. Neutron Monitoring System, (NMS)

1) Purpose:

To provide high flux scram protection from well below the power range to full power conditions.

2) Design (Figure 3)

a) Each RPS subchannel is provided with two sets of two contacts.

b) Each of these redundant sets of contacts can be tripped by its respective NMS trip logic.

3) Functional Description (Figure 3)

a) Intermediate Range Monitor (IRM)

(1) A total of eight IRM instruments, four per RPS channel.

(a) IRM's A, C, E, and G are in RPS Channel A.

(b) IRM's B, D, F, and H are in RPS Channel B.

(2) Logic is 1-out-of-4 twice.

(3) Scram Trip Point Settings

Scram	Set Point
IRM Hi-Hi	120/125 of scale
IRM Inop	Switch not in Operate, or module unplugged, or High Volt. PWR. Sup. Low Voltage

(4) Scram Bypass

(a) Only one IRM per RPS channel may be manually by-passed due to physical arrangement of the bypass switch.

(b) Automatically bypassed in Run, under normal conditions (more later).

b) Average Power Range Monitors, (APRM)

(1) Logic is 1-out-of-3 twice.

(2) A total of six (6) APRM's feed RPS - 3 to each channel.

(a) One APRM in each channel is used twice.

(b)

	RPS A-1	RPS A-2
APRM	A & E	C & E
	RPS B-1	**RPS B-2**
APRM	B & F	B & D

(3) Scram Trip Point Settings

Scram	Set Point
APRM Hi-Hi*	15% (in Startup)
APRM Hi-Hi*	.66W + 54%
APRM Inop	Module unplugged - Switch not in Operate - <14 assigned LPRM's in Operate

(4) Scram Bypass

(a) Only one APRM per RPS channel may be manually bypassed due to physical arrangement of the bypass switch.

(b) The 15% Startup scram is bypassed when the mode switch is in Run. (This is done with the APRM circuitry and is not shown here.*)

c) Companion IRM/APRM

(1) Ensures sufficient overlap of nuclear instrumentation when transferring from Startup to Run and conversely.

(2) Logic is 1-out-of-4 twice.

(3) Interrelationships are as follows

	IRM - companion	- APRM
RPS A-1	A	A
RPS A-1	E	E
RPS A-2	C	C
RPS A-2	G	E
RPS B-1	B	B
RPS B-1	F	F
RPS B-2	D	D
RPS B-2	H	B

*Both trips utilize the same APRM trip unit relay and is discussed in the APRM Lesson Plan.

(4) Scram Trip Point Setting:

APRM downscale (3/125) and companion IRM Hi-Hi or Inop.

(5) Scram Bypass:

Automatically bypassed when mode switch is not in Run.

d) The NMS trip relays (5A-K12's) go two places.

(1) The subchannel scram relays (5A-K14's) and,

(2) The initial fuel loading instrument trip relays

m. Initial Loading Noncoincident Instrument Trips (Figure 3)

1) Purpose:

To provide noncoincident nuclear instrumentation scram capability during initial core loading.

2) Design:

The RPS subchannel trip relay contacts are arranged such that both RPS Channel A & B are tripped upon any nuclear instrumentation trip. (Any single SRM, IRM or APRM trip - this is the meaning of noncoincidence.)

3) Functional Description

a) Four scram sensor relays (5A-K13's) two per RPS channel, each of which is tripped by

(1) SRM Hi-Hi (5 x 10^5 cps) or,

(2) A Neutron Monitor System subchannel relay (5A-K12's). (IRM or APRM trip.)

b) Each scram sensor relay de-energizes Reactor Manual Scram relays (5A-K15's) in both RPS Channels A & B.

c) The Reactor Manual Scram relays de-energize the scram pilot valve solenoids for the RPS channel. (Figure 4)

(1) The S-39A valves are in RPS Channel A.

(2) The @-39B valves are in RPS Channel B.

4) Scram Bypass

a) This scram is normally bypassed by shorting links installed around the auxiliary trip relay contacts in the manual scram circuits.

b) There are two shorting links per RPS channel, a total of four.

c) The shorting links are normally installed after initial fuel loading is complete.

n. Mode Switch in Shutdown (Figure 3)

1) Purpose:

To provide an alternate normal method of scramming the reactor.

2) Design:

This is the only scram that can be caused by actuation of a single component.

3) Functional Description

a) Two contacts serve as inputs to the RPS A3 subchannels.

4) Scram Bypass

a) Automatically, by circuitry, following 2 second time delay.

b) Allows reactor scram to be reset with the mode switch in Shutdown. (Discussed later under F.3.c. Reactor Scram Reset)

o. Manual Scram (Figure 3)

1) Purpose:

Allows operator to scram the reactor in advance of imminent trips, and to follow up automatic scrams.

2) Design

a) Two manual, back-lit red, push-knobs.

b) One per RPS Channel.

3) Functional Description:

Both knobs must be pushed to initiate a reactor scram, one in each RPS Channel.

4) Scram Bypass:

There is no bypass for this scram.

3. Other RPS Functions

a. Backup Scram Valve Controls

1) Purpose:

To provide a means of energizing the backup scram valve solenoid, thus bleeding air from the scram valves - a backup scram.

2) Design (Figure 2)

a) Four solenoid valves arranged in two pairs; either is capable of providing the scram.

b) Power supplies to the solenoids are two 250V DC buses.

c) The solenoids are normally de-energized.

3) Functional Description: (Figure 4)

The logic is disigned such that a trip of:

a) Any subchannel in both RPS channels is required. To energize any of the backup scram valves.

b. Scram Discharge Volume Vent and Drain Valve Controls

1) Purpose:

To provide the necessary circuitry to isolate the scram discharge volume on a reactor scram signal.

2) Design: (Figure 2)

See Section E.5.b.

3) Functional Description: (Figure 2 & 4)

a) Both solenoid valves (S-37A&B), when de-energized, bleed off instrument air which:

(1) Closes the drain valve, and

(2) Closes the vent valves.

b) Solenoid valve S-37A is de-energized by the same relay logic as the S-39A Group I scram pilot valve solenoids.

c) Solenoid valve S-37B is controlled by the S-39B Group I logic.

4) Bypass:

None.

c. <u>Reactor Scram Reset (Figure 3 & 4)</u>

1) Purpose

a) To re-energize the Reactor Scram Relays, the Manual Scram Relays and the scram pilot solenoid valve.

b) To open the scram discharge volume vent and drain valves.

c) An de-energize the backup scram valve solenoids.

2) Design

a) A three position switch:

(1) Spring returned to Normal.

(2) Left, resets groups A-2, A-3. B-2, B-3

(3) Right, resets groups A-1, A-4, B-1. B-4

3) Resetting a Half-Scram

a) Cause of scram must be corrected or bypassed (if possible and not limited by the Technical Specifications or operating procedures).

b) Turn scram reset switch both directions

c) Observe that the scram pilot group lights come on.

4) Resetting a Full Scram

a) Place mode switch in Shutdown or Refuel.

b) Correct cause of scram.

c) Ensures no scram conditions exist, other than Channel A/B Disch Volume High Level (scram annunciator for Hi-Hi-Level - 50 gallons).

d) Bypass scram discharge volume high level scram with keylock switch.

e) Turn scram reset switch both directions (observe scram pilot group lights come on).

f) Leave mode switch in Shutdown or Refuel until scram discharge volume high level scram clears (going to Startup will cause a scram regardless of bypass switch position).

Note:

Once mode switch is taken out of S/D position, returing it to S/D will cause another scram.

5) Time Delays

a) Ten second automatic reset of mode switch is Shutdown, previously mentioned. (Following relays are in Reference 2 prints).

(1) In Mode Switch position except shutdown, 5AK-16 is de-energized, and relay 5A-K17 is energized.

(2) 5A-K16 going to Shutdown picks up (energizes)

(a) Closes one contact in Manual Scram circuitry bypassing the S/D scram.

(b) Opens a contact in the 5A-K17 relay circuitry.

(3) Relay 5A-K17 then de-energizes following a 2 second time delay.

(a) Closes the other contact in the Manual Scram circuitry, bypass complete.

b) Reactor Reset Time Delay (Figure 4)

(1) Purpose:

To ensure that all rods have completed their scram stroke before any scram can be reset.

(2) Functional Description

(a) This time delay provides the above purpose if the mode switch is taken to Refuel instead of Shutdown following a scram.

(b) The 5A-K29 relay are normally de-energized and are controlled by the same logic as the backup scram valves.

(c) When the 5A-K29 relays are picked up on a scram:

i. The contacts shown on Figure open.

ii. Contacts to relay 5A-K30 A & B close.

(d) Following a ten second time delay the 5AK-30 relays pick up and close contacts to the 5A-K30 A & B close.

(e) When the Scram Reset switch is operated in both directions the 5A-K19 relays are then energized.

(f) The 5A-K19 relays close contacts to bypass the 5A-K14 and 5A-K15 relay seal-in contacts, energizing these relays if:

i. The cause of the scram has been corrected, and
ii. S/D mode time delay satisfied, if applicable.

(g) The 5A-K14 and 5A-K15 relays energizing will energize the S-39A & S-39B scram pilot solenoid valves.

d. <u>Individual Rod Scram Test Switch (Figure 4)</u>

1) Purpose:

To provide individual rod scram testing capability, independent or RPS trip action.

2) Functional Description

a) Toggle switches on panel 9-16 interrupt power to the scram pilot valve <u>solenoids</u> scramming individual rods.

b) One switch per control rod trips both the Channel A & B scram pilot solenoids for one drive.

G. RPS OPERATIONAL SUMMARY

1. <u>Advantages of the System</u>

a. Failure of a component. sensor or relay in any subchannel. to trip when required to do so will be backed up by a redundant, identical subchannel capable of performing the entir half-scram function.

b. Failure of a component in any subchannel in the scrammed condition, when not required, will cause a half-scram in the associated channel only. (No rod motion will occur since both channels must be tripped to scram control rods.)

c. The Reactor Protection System is designed to provide the highest pratical degree of plant safety, with continuity of service as the second basic criterion.

1) Theoretically, 1-out-of-2 twice logic is slightly more reliable than 2-out-of-3 and a little less than 1-out-of-2.

2) However, the advantage of this dual logic system is that it can be tested completly at full power operation which contributes significantly to increasing reliability.

2. Possible Problems

a. Of one of the relays fail or a fuse blows, a half-scram in the unaffected channel at the same time could cause one rod, a fourth, or one-half of the control rods to scram - check white lights for scram pilot groups.

H. TECHNICAL SPECIFICATIONS

LIMITING CONDITIONS FOR OPERATION

1.3.1 REACTOR PROTECTION SYSTEM

Applicability

Applies to the instrumention and associated devices which initiate a reactor scram.

Objective

To assure the operability of the reactor protection system.

Specification

The setpoints, minimum number of trip systems, and minimum number of instrument channels that must be operable for each position of the reactor mode switch shall be as given in Table 3.1.A.

SURVEILANCE REQUIREMENTS

4.1 REACTOR PROTECTION SYSTEM

Applicability

Applies to the surveillance of the instrumentation and associated devices which initiate reactor scram.

Objective

To specify the type and frequency of surveillance to be applied to the protection instrumentation.

Specification

A. Instrumentation systems shall be functionally tested and calibrated as indicated in Tables 4.1.A and 4.1.B respectively. (Not incleded here).

B. Daily during reactor power operation at greater than or equal to 25% thermal power, the maximum total peaking factor shall be checked and the scram and APRM Rod Block settings given by equations in specifications 2.1.A.1 and 2.1.B shall be calculated.

C. When it is determined that a channel is failed in the unsafe condition, the other RPS channels that monitor the same variable shall be functionally tested immediately before the trip system containing the failure is tripped. The trip system containing the unsafe failure may be tripped for short periods of time to allow functional testing of the other trip system. The trip system may be in the untripped position for no more than eigh hours per functional test period for this testing.

TABLE 3.1.A
REACTOR PROTECTION SYSTEM (SCRAM) INSTRUMENTATION REQUIREMENT

Min. No. of Operable Inst. Channels Per Trip System (1)	Trip Function	Trip Level Setting	Modes in Which Function Must Be Operable: Shut-down	Refuel(7)	Startup/Hot Standby	Run	Action(1)
1	Mode Switch in Shutdown		X	X	X	X	1.A
1	Manual Scram		X	X	X	X	1.A
	IRM (16)						
3	High Flux	≤ 120/125 Indicated on scale	X	X	X	(5)	1.A
3	Inoperative			X	X	(5)	1.A
	APRM (16)						
2	High Flux	See Spec. 2.1.A.1				X	1.A or 1.B
2	High Flux	≤ 15% rated power		X	X(17)	(15)	1.A or 1.B
2	Inoperative	(13)		X	X(17)	X	1.A or 1.B
2	Downscale	≥ 3 Indicated on Scale		(11)	(11)	X(12)	1.A or 1.B
2	High Reactor Pressure	≤ 1055 psig		X(10)	X	X	1.A
2	High Drywell Pressure (14)	≤ 2 psig		X(8)	X(8)	X	1.A
2	Reactor Low Water Level (14)	≥ 538" above vessel zero		X	X	X	1.A
2	High Water Level in Scram Discharge Tank	≤ 50 Gallons	X	X(2)	X	X	1.A

TABLE 3.1.A (Continued)

Min. No. of Operable Inst. Channels Per Trip System (1)	Trip Function	Trip Level Setting	Modes in Which Function Must Be Operable: Refuel(7)	Startup/Hot Standby	Run	Action(1)
4	Main Steam Line Isolation Valve Closure	≤ 10% Valve Closure	X(3)(6)	X(3)(6)	X(6)	1.A or 1.C
2	Turbine Cont. Valve Fast Closure	Upon trip of the fast acting solenoid valves	X(4)	X(4)	X(4)	1.A or 1.D
4	Turbine Stop Valve Closure	≤ 10% Valve Closure	X(4)	X(4)	X(4)	1.A or 1.D
2	Turbine Control Valve - Loss of Control Oil Pressure	≥ 550 psig	X(4)	X(4)	X(4)	1.A or 1.D
2	Turbine First Stage Pressure Permissive	≤ 154 psig	X(18)	X(18)	X(18)	(19)
2	Turbine Condenser Low Vacuum	≥ 23 In. Hg, Vacuum	X(3)	X(3)	X	1.A or 1.C
2	Main Steam Line High Radiation (14)	≤ 3X Normal Full Power Background (20)	X(9)	X(9)	X(9)	1.A or 1.C

NOTES FOR TABLE 3.1.A

1. There shall be two operable or tripped trip systems for each function. If the minimum number of operable instrument channels per trip system cannot be met for both trip systems, the appropriate actions listed below shall be taken.

   A. Initiate insertion of operable rods and complete insertion of all operable rods within four hours.

   B. Reduce power level to IRM range and place mode switch in the Startup/Hot Standby position within 8 hours.

   C. Reduce turbine load and close main steam line isolation valves within 8 hours.

   D. Reduce power to less than 30% of rated.

2. Scram discharge volume high bypass may be used in shutdown or refuel to bypass scram discharge volume scram with control rod block for reactor protection system reset.

3. Bypassed if reactor pressure $\leq$ 1055 psig and mode switch not in run.

4. Bypassed when turbine first stage pressure is less than 154 psig.

5. IRM's are bypassed when APRM's are onscale and the reactor mode switch is in the run position.

6. The design permits closure of any two lines without a scram being initiated.

7. When the reactor is subcritical and the reactor water temperature is less than 212°F, only the following trip functions need to be operable:

   A. Mode switch in shutdown

   B. Manual scram

   C. High flux IRM

   D. Scram discharge volume high level

   E. APRM 15% scram

8. Not required to be operable when primary containment integrity is not required.

9. Not required if all main steamlines are isolated.

10. Not required to operate when the reactor pressure vessel head id not bolted to the vessel.

11. The APRM downscale trip function is only active when the reactor mode switch is in run.

12. The APRM downscale trip is automatically bypassed when the IRM instrumentation is operable and not high.

13. Less than 14 operable LPRM's will cause a trip system trip.

14. Channel shared by Reactor Protection System and Primary Containment and Reactor Vessel Isolation Control System. A channel failure may be a channel failure in each system.

15. The APRM 15% scram is bypassed in the Run Mode.

16. Channel shared by Reactor Protection System and Reactor Manual Control System (Rod Block Portion). A channel failure may be a channel in each system.

17. Not required while performing low power physics tests at atmospheric pressure during or after refueling at power levels not to exceed 5 MW(t).

18. Operability is required when normal first-stage pressure is below 30% ($\leq$147 psig).

19. Action 1.A or 1.D shall be taken only if the permissive fails in such a manner to prevent the affected RPS logic from performing its intended function. Otherwise, no action is required.

20. An alarm setting of 1.5 times normal background at rated power shall be established to alert the operator to abnormal radiation levels in primary coolant.

2.3.1 Bases

The reactor protection system automatically initiates a reactor scram to:

1. Preserve the integrity of the fuel cladding.
2. Preserve the integrity of the reactor coolant system.
3. Minimize the energy which must be absorbed following a loss of coolant accident, and prevent criticality.

This specification provides the limiting conditions for operation necessary to preserve the ability of the system to tolerate single failures and still perform its intended function even during periods when instrument channels may be out of service because of maintenance. When necessary, one channel may be made operable for brief intervals to conduct required functional tests and calibrations.

The reactor protection system is made up of two independent trip systems. There are usually four channels provided to monitor each critical parameter with two channels in each trip system. The outputs of the channels in a trip system are combined in a logic such that either channel trip will trip that system. The simultaneous tripping of both trip systems will produce a reactor scram.

The system has a reliability greater than that of a 2 out of 3 system and somewhat less than that of a 1 out of 2 system.

With the exception of the Average Power Range Monitor (APRM) channels, the Intermediate Range Monitor (IRM) channels, the Main Steam Isolation Valve closure and the Turbine Stop Valve closure, each trip sytem logic has one instrument channel. Whe the minimum condition for operation on the number of operable instrument channels per untripped protection trip system is met or if it cannot be met and the effected protection trip system is placed in a tripped condition, the effectiveness of the protection system is preserved; i.e., the system can tolerate a single failure and still perform its intended function of scramming the reactor. Three APRM instrument channles are provided for each protection trip system.

Each protection trip system has one more APRM than is necessary to meet the minimum number required per channel. This allows the bypassing of one APRM per protection trip system for maintenance, testing or calibration. Additional IRM channels have also been provided to allow for bypassing of one such channel. The bases for the scram setting for the IRM, APRM, high reactor pressure, reactor low water level, MSIV closure, turbine control valve fast closure, turbine stop valve closure and loss of condenser vacuum are discussed in the Lesson Plans dealing with that equipment or instrumentation.

3.1 Bases

Instrumentation (pressure switches) for the drywell and provided to detect a loss of coolant accident and initiate the core standby cooling equipment. A high dryell pressure scram is provided at the same setting as the core cooling system (CSCS) initiation to minimize the energy which must be accommodated during a loss of coolant accident and to prevent return to criticality. This instrumentation is a backup to the reactor vessel water level instrumentation.

High radiation levels in the main steam line tunnel above that due to the normal nitrogen and oxygen radioactivity is an indication of leaking fuel. A scram is initiated whenever such radiation level exceeds three times normal background. The purpose of this scram is to reduce the source of such radiation to the extent necessary to prevent release of radioactive material to the turbine. An alarm is initiated whenever the radiation level exceeds 1.5 times normal background to alert the operator to possible seroius radioactivity spikes due to abnormal core behavior. The air ejector off-gas monitors serve to back up the main steam line monitors to provide further assurance against release of radioactive materials to site environs by isolating the main condenser off-gas line to the main stack.

A reactor mode switch is provided which actuates or bypasses the various scram functions appropriate to the particular plant operating status.

The manual scram function is active in all modes, thus providing for a means of rapidly inserting control rods during all modes of reactor operation.

The IRM system (120/125 scram) in conjunction with the APRM system (15[illegible] scram) provides protection against excessive power levels and short reactor periods in the startup and intermediate power ranges.

The control rod drive scram system is desinged so that all of the water which is discharged from the reactor by a scram can be accommodated in the discharge piping. The discharge volume tank accommodates in excess to 50 gallons of water and is the low point in the piping. No credit was taken for this volume in the design of the discharge piping as concerns the amount of water which must be accommodated during a scram. During normal operation the discharge volume is empty: however, should it fill with water, the water discharged to the piping from the reactor could not be accommodated which would result in slow scram times or partical control rod insertion. To preclude this occurance, level switches have been provided in the instrument volume which alarm and scram the reactor when the volume of water reaches 50 gallons. As indicated above, there is sufficient volume in the piping to accommodate the scram without inpairment of the scram times or amount of insertion of the control rods. This function shuts the reactor down while sufficient volume remains to accommodate the discharge water and precludes the situation in which a scram would be required but not be able to perform its function adequately.

A source range monitor (SRM) system is also provided to supply additional neutron level information during startup but has no scram functions. Thus, the IRM is required in the Refuel and Startup modes. In the power range the APRM system provides required protection. Thus, the IRM System is not required in the Run mode.

The high reactor pressure, high drywell pressure, reactor low water level and scram discharge volume high level scrams are required for Startup and Run modes of plant operation. they are, therefore, required to be operable for these modes of reqctor operation.

The requirement to have the scram functions as indicated in Table 3.1.1 operable in the Refule mode is to assure that shifting to the Refuel mode during reactor power operation does not diminish the need for the reactor protection system.

The turbine condenser low vacuum scram is only required during power operation and must be bypassed to start up the unit. Below 154 psig turbine first stage pressure (30% of rated), the scram signal die to turbine stop valve closure, turbine control valve fast closure, and turbine control valve loss of contol oil pressure, is bypassed because flux and pressure scram are adequate to protect the reactor.

Because of the APRM downscale limit of $\geq 3\%$ when in the Run mode and high level limit of $\leq 15\%$ when in the Startup Mode, the transition between the Startup and Run Modes must be made with the APRM instrumentation indicating between 3% and 15% of rated power or a control rod scram will occur. In addition, the IRM system must be indicating below the High Flux setting (120/125 of scale) or a scram will occur when in the Startup Mode. For normal operating conditions, whese limits provide assurance of overlap between the IRM system and APRM system so that there are no "gaps" in the power level indications (i.e., the power level is continuously monitored from beginning of startup to full power and from full power to shutdown). When power is being reduced, if a transfer to the Startup mode is made and the IRM's have not been fully inserted (a maloperational but not impossible condition) a control rod block immediately occurs so that reactivity insertion by control rod withdrawal cannot occur.

Revision ____________

Date ____________

BWR SYSTEMS

LESSON PLAN

A. REACTOR MANUAL CONTROL SYSTEM AND ROD POSITION INFORMATION SYSTEM

B. REFERENCES

1. BWR Systems Manual, Chapter 7.2
2. GEK 45837 - Reactor Manual Control - Browns Ferry
3. GEK 32539A - Rod Position Information System - Browns Ferry
4. Browns Ferry Procedures
   a. Operating Instructions OI-85
   b. Surveillance Instructions SI4.10.A.1
5. Browns Ferry Prints
   a. Mechanical Control Diagram 47W610-85
   b. Mechanical Logic Diagram 47W611-85
6. Final Safety Analysis Report - Browns Ferry
7. Technical Specifications - Browns Ferry
8. Card File 7.2

C. OBJECTIVES

1. To understand the purpose of the system.
2. To become familiar with major system components and their functions.
3. To understand system instrumentation, interlock, alarms, and setpoints.
4. To understand the automatic actions and limitations of the system.
5. To become familiar with system operation.

D. GENERAL DESCRIPTION (Figure 1)

1. Purpose - Reactor Manual Control System (RMCS)

a. To cause control rod movement by providing the necessary electrical signals to the solenoid operated directional control valves on the CRD hydraulic control unit.

1) Controls Valve Operating Sequence

2) Controls Valve Timing

b. To prohibit movement of control rods during certain potentially unsafe conditions.

2. Purpose - Rod Position Information System (RPIS)

To provide operator and related systems with control rod position and alarm information.

3. Major Components of Reactor Manual Control System

a. Full Core Display (Figure 2)

b. Four Rod Display (Figure 3)

c. Pushbutton Select Matrix (Figure 4)

d. Manual Control Switches on 9-5 Panel

1) CRD Control Switch

2) CRD Notch Override Switch

3) CRD Rod Power Switch

4) Rod Draft Alarm Test Switch

5) Timer Test Switch

e. Indicating Lights on Panel 9-5 Apron Section

1) Movement Control Lights

2) Timer Malfunction Lights

3) Refuel Mode One Rod Permissive Light

f. Automatic Sequence Timer and Relays

4. Major Components of Rod Position Information System

a. Reed switch probe in center of control rod drive

b. Displays on panel 9-5 full core and four rod displays

E. COMPONENT DESCRIPTION

1. Full Core Display (Top of Panel 9-5) (Figure 2)

   a. Full Core Display consists of:

      1) Individual 4 Light Display

      2) Digital Readouts

      3) Local Power Range Monitor (LPRM) Hi-Low Indicating Lights

   b. Arrangement

      Displays are arranged on panel in the same configuration as the rods in the core.

   c. Individual 4 Light Display

      1) Indicates Control Rod Status

      2) White Light

         Indicates rod is selected (labeled with rod's core location code)

      3) Red Light

         Indicates Rod Drift (labeled drift)

      4) Amber Light

         Indicates accumulator trouble (labeled Accum)

         a) Lo N_2 Pressure 970 psig

         b) Hi H_2O level 37 cc leakage pass accumulator seal

      5) Blue Light

         Indicates <u>both</u> inlet and outlet scram valves open (labeled scram)

   d. Digital Readout

      1) Gives notch position of rod from Rod Position Information System (RPIS)

2) Indicates rod limits with red and green back lighting

a) Red back light for full out

b) Green back light for full in

e. LPRM Hi-Lo Indicating Lights

1) Purpose

To indicate when LRPM chamber outputs are not within normal power range flux levels.

2) White Lights

Hi flux above acceptable power level

3) White Lights

Lo flux - LPRM not yet on scale

4) Not part of reactor manual control, will be discussed in depth in LPRM lesson plan.

2. Four Rod Display (Panel 9-5 below full core display) (Figure 3)

a. Displays group containing selected rod and adjacent 3 rods.

1) Core is divided into groups for rod selection purposes only (Figure 5).

2) Each group contains 4 rods in a square pattern surrounded by an LPRM string at each corner.

3) The LPRM string locations are represented by dots on push-button select matrix.

b. LPRM string outputs displayed on meters.

1) Shows inputs to rod block monitor system.

2) Displays power around rod to be moved.

3) If LPRM is bypassed, meter will read zero and white LPRM bypassed light beside meter will light (Refer to RBM Lesson Plan).

c. Most groups contain 4 rods and 4 LPRM strings. However, groups at the periphery may contain only 1, 2, or 3 rods and LPRM strings. Digital displays for missing rods will be blank.

d. Center white lights indicate which rod of group is selected.

3. Pushbutton Select Matrix (Panel 9-5 Apron Section) (Figure 4)

a. Arrangement

Arrangement of pushbuttons corresponds to arrangement of rods in core.

b. Pushbuttons

Each pushbutton selects one of the 185 rods in the core. More than one rod cannot be selected at the same time. Pushing a second pushbutton deselects the first.

c. Backlighting (White)

1) Bright backlighting on pushbutton indicates selected rod.

2) Dim backlighting is used by Rod Sequence Control System for rod group identification.

d. LPRM Input to RBM System

Pushbutton also selects LPRM strings for input to meters and to Rod Block Monitor (RBM) system; initiates RBM nulling sequence (discuss in Rod Block Monitor presentation).

4. Manual Control Switches on 9-5 Panel (Figure 4)

a. CRD Control Switch

1) Three Positions (Listed Counter Clockwise)

a) Rod Out Notch

b) Off

c) Rod In

2) Spring Return to Off

3) Initiates notch in and notch out cycles (notch movement means moving control rod from one even position indication to the next, i.e., one notch on the CRD index tube).

NOTE: Also supplies signal to RSCS Group Notch Control Logic indicating direction of control rod movement.

4) If held in notch out, will complete one notch out cycle and stop.

5) If held in Rod In, will move rod continuously in until released.

b. CRD Notch Override Switch

1) Three Positions (Listed Counter Clockwise)

a) Notch Override

b) Off

c) Emergency In

2) Spring Return to Off

3) Notch Override Position

a) Allows for continous withdrawal of control rod.

b) Used in conjunction with Rod Movement Control Switch Notch Out position.

c) Insures deliberate operator action for continuous withdrawal - must use two hands.

d) Must be moved before or simultaneously with rod movement control switch.

e) Amber light above switch lights during notch override action.

4) Emergency In Position

a) Bypasses all interlocks to insert rod except Rod Worth Minimizer (RWM) insert block and any select blocks.

b) Acts directly on directional control valves - bypasses timer.

c) No settle function - forces water past seals in CRD while settling into notch.

c. CRD Rod Power Switch

1) Two Positions - On, Off

2) Furnishes Power to Select Matrix

3) Only Method of Manually De-selecting All Rods

4) Never Turned Off During Normal Operation

d. Rod Drift Alarm Test Switch

1) Purpose

To test drift alarm circuitry.

2) Three Positions (Listed Counter-Clockwise)

a) Test

b) Neutral

c) Reset

3) Spring Return to Neutral

4) Operation

a) If a rod passes an odd numbered reed switch position after the normal timer cycle, the rod drift alarm will actuate. This switch will provide the reset of the drift light after rod is in the proper - even numbered - position.

b) Any rod that moves from an even numbered position when it is not selected or being positioned, will give a drift alarm immediately.

c) Testing is performed by holding the test switch to "test" while moving a control rod. The drift alarm will actuate when rod passes odd numbered reed switch.

d) During normal rod movement, the drift alarm is bypassed on the selected rod while the automatic sequence timer is cycling to permit the normal sequence without an alarm.

e. Timer Test Switch

1) Purpose

To test the operation of the auxiliary timer and select block functions.

NOTE: A select block is an interlock which deenergizes the select power to the select matrix deselecting the selected rod and preventing further selection of rods until the block has been cleared.

2) The withdrawal portion of a normal notch out sequence takes 1.5 seconds.

3) A 2 second auxiliary timer monitors this interval.

4) If withdrawal signal is sent to directional control valves for more than two seconds, auxiliary timer will time out.

5) When auxiliary timer times out, it will generate a select block which deselects rod.

6) This prevents a faulty master timer from causing an uncontrolled withdrawal signal.

7) Aux. timer is defeated by CRD Notch Override switch.

8) Auxiliary timer functions only during withdraw portion of notch out cycle; it does not operate during any other kind of rod movement.

9) Three Position Switch

a) Test

b) Neutral

c) Reset

10) Spring Return to Neutral

11) Test Position

a) Allows Testing of Auxiliary Timer

b) Starts Auxiliary Timer and Lights Block Test Light

c) After 2 seconds, the block test goes out, select block light goes on, and select block deselects rod.

12) Reset position - resets select block after test or after real timer malfunction has been cleared.

13) Neutral - no contacts made

f. Switches on panel 9-5 apron section not part of Reactor Manual Control System.

1) Manual Scram Pushbuttons

a) Part of Reactor Protection System

b) Allow operator to manually scram reactor control rods

2) Scram Reset Switch (Not Shown)

a) Part of Reactor Protection System

b) Allows operator to reset scram relays after initiation signal has cleared.

3) Mode Switch

a) Determines Mode of Reactor Operation

1) Shutdown

2) Refuel

3) Startup

4) Run

b) Reactor parameters (temperature, pressure, neutron flux, etc.) determine which mode reactor can be operated in without protective action (scram or isolation).

c) Interlocks with Reactor Manual Control System on many rod blocks (See Section I).

5. Indicating Lights on Panel 9-5 (Apron Section) (Figure 4)

   a. Movement Control Lights

      1) Rod Out Permissive

         a) White Light

         b) Indicates No Rod Withdraw Blocks Present

            NOTE: RSCS Rod Withdraw Blocks Do Not Affect This Light.

         c) Rod cannot be withdrawn if light is not lit.

         d) Has no effect on insert motion, i.e., rod can be inserted with light out.

      2) Rod Out Settle

         a) Amber Light

         b) Indicates rod is in settle portion of cycle.

         c) Directional control valve 120 is open.

      3) Rod Out

         a) Red Light

         b) Indicates withdraw signal sent to control valves.

         c) Directional control valves 120 and 122 are open.

      4) Rod In

         a) Green Light

         b) Indicates insert signal sent to control valves.

         c) Directional control valves 121 and 123 are open.

   b. Timer Malfunction Lights

      1) Select Block

a) Red Light

b) Indicates select block from timer malfunction

2) Block Test

a) White Light

b) Illuminated when timer test switch taken to test.

c) Used for timing auxiliary timer

c. Refuel Mode One Rod Permissive Light

1) White Light

2) Lights in refuel mode only when all rods are at 00 or in full in overtravel (discussed later under Rod Position Information System).

6. Automatic Sequence Timer (Figures 6 and 7)

a. Purpose

To control the sequence timing of the normal insert and withdrawal rod movements. One timer controls both cycles.

b. Multiflex Timer

1) Driven by synchronous motor through solenoid operated clutch.

2) Cam plate operates contacts

3) Rset by spring when clutch is disengaged.

c. 7 Contacts on Timer

1) Timer Interlock and Reset (0-9 sec.)

a) Seals in Timer Sequence

b) Resets Timer at End of Sequence

2) Unlatch (0.20-0.85 sec.)

a) Energizes insert bus (valves 121, 123) to drive rod in far enough to release collet fingers from index tube notch so that rod can then be driven past that notch.

b) Part of Withdraw Cycle

3) Drive Out (0.85-2.35 sec.)

a) Energizes withdraw bus (valves 120, 122) to drive rod out past index tube notch.

b) Main Part of Withdraw Cycle

c) Follows Unlatch

4) Settle Out (1.2-8.35 sec.)

a) Energizes settle bus (valve 120) to allow next notch in index tube to settle onto collet fingers.

b) Part of Withdraw Cycle

c) Overlaps drive out to keep from shutting and then immediately reopening valve 120.

5) Drive In (0.4-3.3 sec.)

a) Energizes insert bus to drive rod in a little past next notch.

b) First Part of Insert Cycle

6) Settle In (2.0-7.8 sec.)

a) Energizes settle bus (valve 120) to allow next notch in index tube to settle back onto collet fingers.

b) Completes Insert Cycle

c) Overlaps drive in cycle to reduce pressure transients caused by reversal of flow in withdraw and insert headers.

7) Cycle Auxiliary (0-9.8 sec.)

a) Generates rod driving signal to seal in select matrix and bypass drift alarm.

b) Closed entire cycle until timer is completely reset.

8) Either settle (insert or withdraw) timing signals RSCS Group Notch Control that a timing cycle has occurred.

7. Rod Position Information System (RPIS) (Figure 8)

a. System consists of:

1) Probe inside CRD piston tubes containing 53 reed switches.

2) Electronics to translate reed switch closures to numeric position information.

b. Reed Switch Assembly

1) 53 Reed Switches

2) Designated S00 through S52

Switch Switch Number	Inches From Full Insert	Control Room Display	Rod Position
S51	-1-1/4	Green light - No readout	Overtravel beyond full-in.
S52	-3/8	Green light - No readout	Normal full-in (latched)
S00	0	00 readout	Normal full-in (latched)
S01	3	01 readout	Halfway between 00 and 02
S02	6	02 readout	Latched position 02
S48	144	48 readout	Normal full-out (latched)
S49	144	Red light - No readout	Normal full-out (latched)
S50	146	"Overtravel" annunciation - no readout	Overtravel beyond full-out

3) Red and Green Lights in Table Above

a) Red and green lights show up as backlighting on digital displays.

b) Switches S52 and S00 close nearly simultaneously to show 00 with green backlighting.

c) Switches S48 and S49 close simultaneously to show 48 readout with red backlighting.

d) Switches S52 and S49 are also used by the RSCS.

(1) Provide "Full-In", "Full-Out" signals for RSCS logic at >50% rod density.

(2) Bypass switch for each rod will allow bypassing S52 <u>or</u> S49 (See RSCS Lesson Plan).

e) S51 picked up after scram - necessary since rods are driven to in overtravel and S52 won't be picked up, which maintains green light.

f) Backlighting not present on 4 rod display, only on full core display.

4) Position Readouts

a) On Full Core Display (Figure 2)

b) On 4-Rod Display (Figure 3 and 5)

c. Translation Electronics

1) Each position probe (each CRD Unit) has a printed circuit card in panel 9-27 in auxiliary instrument room.

2) Card translates reed switch closures to numeric readout.

3) If electronic malfunction is detected, an RPIS INOP is generated, indicating RPIS data may not be correct. INOP includes:

a) Card Pulled

b) Internal Logic Stall

4) RPIS INOP Gives Select Block

d. Provides position information to:

1) Full Core Display

2) Four Rod Display

3) Process Computer and Rod Worth Minimizer

4) Rod Select Logic (Refuel All Rods In Information)

5) Drift Circuitry (Odd Reed Switches)

6) Scram Timing Recorder

7) RSCS (Full-In, Full Out ONLY)

F. INSTRUMENTATION

1. Control Room

a. Full Core Display

b. Four Rod Display

c. Pushbutton Select Matrix

2. Alarm, Interlocks

a. Annunciators

Annunciator	Description
Rod Drift	Rod not in latched position when rod not being driven by Reactor Manual Control System.
RWM Rod Block	Select. Insert. or Withdraw block from Rod Worth Minimizer
Rod Withdrawal Block	Rod withdraw motion is blocked (See Table 1 for list of conditions causing rod blocks).
Rod Select Block-Timer Malfunction	Rod select block caused by timer failing in withdraw cycle.
RPIS Inoperative	Malfunction in Rod Position Information System
Rod Overtravel	Indicates a control rod drive has been withdrawn past 48. - If occurs, indicates that rod is uncoupled from drive.

b. System Interlocks

1) Internal System Interlocks

a) RPIS Inop Causes Select Block

b) Timer Malfunction Causes Select Block

c) Rod Driving Signal Bypasses Odd Reed Switch Drift Alarm

2) Interlocks on RMCS from Other Systems - Rod Blocks

a) Select Block:

(1) Rod Worth Minimizer

(2) Rod Sequence Control System

b) Insert Block

(1) From Rod Worth Minimizer

(2) From Rod Sequence Control System

c) Withdraw (Out) Blocks (See Table and Figure 1)

(1) From Nuclear Instrumentation

(2) From Rod Worth Minimizer

(3) From Refueling Equipment

(4) From Rod Sequence Control System

NOTE: Rod blocks are present while refueling to keep from moving rods while core modifications are in progress. This prevents adding reactivity to core by two different modes simultaneously (moving rods and adding fuel). which would be a violation of basic operational philosopny.

(5) From Scram Instrument Volume

(6) From Mode Switch in Shutdown

NOTE: Shutdown mode implies all rods inserted. To assure this. mode switch sends scram signal to Reactor Protection System for initial 2 seconds that switch is in shutdown, inserting any rods that might be withdrawn. and sends a continous rod out block to prohibit any rod withdrawal.

3) Interlocks on Other Systems from RMCS

Refueling equipment power interlocks from all rods in.

NOTE: This prevents loading fuel into the core while all rods are not full in. This minimizes the possibility of an accidental criticality during fuel loading, since, if fuel is loaded per design, reactor should be shut down under all conditions with full core loaded and all rods in (Refer to Refueling Lesson Plan).

G. SYSTEM OPERATIONAL SUMMARY (Figure 10)

1. Rod Selection

   a. Rod Select Power

   b. RSCS Interlocks Satisfied

   c. No Select Block

      1) RPIS Inop

      2) RWM Select Block

      3) These select blocks seal in during the timex cycle so that a rod cannot be deselected during rod movement.

   d. No Timer Malfunction Select Block

      1) Not bypassed by rod driving signal so it can deselect during timer cycle.

      2) Only detects malfunction of drive out portion of timer cycle.

   e. Select matrix pushbutton chooses rod and energizes select relays if rod in proper sequence.

   f. Select relays connect timer to proper directional control valves.

2. Notch In Cycle

   a. Rod Selected

   b. Rod movement control switch moved to "Rod In" position (not in Off)

c. No RSCS Insert Blocks

d. No RWM Insert Blocks

e. Rod Movement Control Switch Not In Rod Out Notch Position

f. Insert motion is selected and sealed in for one timer cycle, allowing drive in and settle in contacts to act on select relays, and operates proper stabilizing valves.

3. Continuous In

a. Uses Basic Notch In Cycle

b. Generated by holding Rod Movement Control Switch in the Rod In position.

c. This interrupts timer motor power at beginning of Drive In cycle (0.4 sec.) stopping timer at that point in sequence.

d. Insert bus holds valves 121 and 123 open during this period, and proper stabilizing valves.

e. When Rod Movement Control Switch is released, timer motor restarts, completing Notch In cycle, moving control rod one additional notch.

f. Insert block bypasses Continuous In, completing timer cycle and blocking further insert motion.

g. RSCS Group Notch Control also bypasses Continuous In, allowing only notch insertion.

4. Notch Out

a. Rod Selected

b. Rod movement control switch moved to Rod Out Notch position

c. No RSCS Out Blocks

d. No Rod Out Blocks

e. No RWM Out Blocks

f. RBM Nulled (Only Necessary if >30% Power)

g. Rod movement control switch not in Rod In position.

h. Withdraw motion is selected and sealed in for one timer cycle, allowing unlatch, drive out and settle out contacts to act on select relays, and proper stabilizing valves.

5. Rod Out Notch Override

a. Requires simultaneous actuation of both Rod Movement Control Switch and Rod Out Notch Override Switch.

b. Both switches must be held until one notch before movement is terminated.

c. Uses Basic Notch Out Cycle

d. Interrupts timer motor power at beginning of drive out cycle (0.85 sec.) stopping timer motor at that point in sequence.

e. Withdraw bus holds valves 120 and 122 open during this time and proper stabilizing valves.

f. When switches are released, timer completes cycle, moving rod one more notch.

g. Withdraw block will bypass notch override and restart timer motor to complete notch out cycle and causes out block.

h. RSCS Group Notch Control also bypasses the Notch Override allowing only Notch Withdrawal.

i. Both Rod Out Notch Override and Continous In are bypassed by RPIS Inop so that timer will complete cycle, removing rod driving bypass from select block. which deselects rod.

6. Emergency In

a. Allows for insertion of rods if the timer has failed.

b. Bypasses timer sequencing and energizes the 121 and 123 solenoid directly.

c. No settle function is provided.

d. Only RWM Insert Blocks will override Emergency In.

7. Timer Malfunction

a. Checks length of time drive out contacts stay closed.

b. Bypassed by Notch Override

c. Causes select block if Drive Out contacts closed longer than 2 seconds.

8. Drift Alarm

a. Odd reed switch closes or rod not select and driving is not at a latched position.

b. Check to see if that rod is driving.

c. If that rod not driving, drift alarm.

d. Test switch bypasses rod driving signal, causing drift alarm during normal rod motion.

H. RELATIONSHIPS TO OTHER SYSTEMS

1. Power Supplies

a. Select power and RPIS power from uninterruptible power M-M-G set.

b. All other power from instrument bus

2. Outputs to Other Systems

a. Operates directional control valves (-120, -121, -122, -123) and stabilizing valves in CRD Hydraulic System.

b. Provides rod position information to RWM, process computer, and RSCS.

c. Provides select information to RBM, RWM and RSCS Systems.

d. Provides direction and movement information to the RSCS.

3. Rod Blocks from Other Systems

a. Neutron Monitoring System

b. Rod Worth Minimizer

c. Refueling Equipment

d. Rod Sequence Control System

e. Scram Instrument Volume

f. Mode Switch in Shutdown

I. TECH SPEC REQUIREMENTS

There are no Tech Spec requirements directly associated with the Reactor Manual Control System. These are listed in table 1 along with other Rod Block functions.

Revision ____________

Date ____________

BWR SYSTEMS

LESSON PLAN

A. OFF GAS SYSTEM

B. REFERENCES

1. Boiling Water Reactor Systems Manual Chapter 8.1
2. Browns Ferry FSAR Chapter 9.5
3. Browns Ferry FSAR Chapter 9.6
4. Browns Ferry FSAR Chapter 1.6
5. Peachbottom BWR Discussion 11.2
6. BWR Radwaste Manual Chapter 3.1

C. OBJECTIVES

1. Purpose and Design Basis of the System
2. Major System Components and Flow Paths
3. Off-Gas Sources and Production
4. System Instrumentation and Isolations
5. Technical Specifications

D. BRIEF DESCRIPTION

1. Design Basis

a. To reduce the off-site exposures at the nearest site boundary to less than the established maximum limit (10 mr/year). based on a nominal plant with 100;000 µc/second noble gas discharge after a 30 minute holdup time. The system must be capable of safe mechanical operation at release rates up to 300,000 µc/second.

b. To minimize the discharge of particulate daughter products.

c. To allow response time to abnormal conditions.

d. To minimize explosion hazard of hydrogen and oxygen mixture.

e. To minimize personnel exposure.

2. Major Components (Use Transparency) (Figure 1)

   a. Main Condenser Off Gas Outlet

   b. 3-Stage Steam Jet Air Ejectors

   c. Pre-Heater

   d. Catalytic Recombiner

   e. Off-Gas Condenser

   f. Water Separator

   g. Dehumidification Coil

   h. 6 hour Holdup Line

   i. Cooler Condenser

   j. Refrigerated Glycol Solution Storage and Pumping Equipment

   k. Moisture Separator

   l. Reheater

   m. Pre-Filter

   n. Charcoal Filters

   o. Afterfilter

   p. Stack

E. COMPONENT DESCRIPTION

1. Main Condenser (Figure 2)

   a. Suction from both end of condensers through 2 12" lines.

   b. "A" and "C" condensers have a 14" vacuum breaker on them which can be operated from control room panel 8 to vent air into the condensers and break vacuum.

      Note: Refer to Condenser and Circulating Water lesson plan for more detail of condenser design.

2. Off Gas Inlet Isolation Valves (Valves 2 - 7 on Figure 2)

   a. 12" electric-motor operated butterfly valves (6 valves).

   b. Located in low pressure feedwater heater area near condenser.

   c. No automatic features to valves operator controlled from control room panel 8 switches.

3. Precooler

   a. Located just above SJAE room in turbine building

      1) Adjacent to condenser vacuum hogging pumps

4. Steam Jet Air Ejector (SJAE) (Figure 3)

   a. Three-stage unit located in SJAE room off turbine building.

      1) First Stage

         a) Utilizes inter-condenser for exhaust

            (1) Condensate system provides cooling medium

         b) Normal steam flow path from main steam equalizing header through motor operated isolation valve and pressure control valve set at ≈200 psig.

         c) Alternate steam flow path from house boiler for startup.

      2) Second Stage

         a) Takes a suction on intercondenser.

         b) Steam driving flow same as first stage.

      3) Third Stage Discharges to Off-Gas Pre-Heater

         a) Normal steam from mian steam equalizing header through a motor operated isolation valve and a pressure control valve set at ≈200 psig

         b) Alternate steam flow path from house boiler for startup.

         c) Dilutes hydrogen gas concentration to less than 4% by volume.

         d) Provides system driving force.

e) Air line from service air for system purge prior to startup.

f) Provides driving force for H_2 analyzer sample.

4) Normal flow rate of dry gases at air ejector at $130^{o}F$ and 1 atm.

a) Between 200 and 300 SCFM

b) Off-Gas Composition

154 SCFM H_2 (from Reactor Water Decomposition)
77 SCFM O_2 (from Reactor Water Decomposition)
18.5 SCFM Air Leakage (Inleakage to Turbine Condenser)
46 SCFM Water Vapor (Saturate
= 195.5 SCFM

5) Valve Control (SJAE Unit "A" Described Unit "B" Functionally Identical)

a) Motor Operated Steam Admission Valves (Valves 155 and 172 on Figure 3) from Main Steam.

(1) Normal Open through Control Switch

(2) Auto Opens if:

(a) Auto start if SJAE "B" Initiated or

(b) Condenser Vacuum is not >20" Hg Vacuum or

(c) SJAE "A" does not have a start signal to it.

b) Air operated steam admission valves (valves 15) and 166 on Figure 3) from main steam

(1) Normal open and control steam pressure at 200 psig through control switch and timed delay it.

(a) SJAE "A" has a start signal,

(b) Condenser is >20" Hg vacuum,

(c) SJAE "B" steam isolation motor operated valves are closed.

(d) Condensate pressure to SJAE condenser "A" is $\geq$60 psig,

(e) SJAE condenser "A" condensate inlet and outlet valves are not closed, and

(f) If time delay above has elapsed steam pressure must be above 190 psig or valves will close.

(2) Auto open with same permissives above if control switch is in auto and an Auto Start of SJAE "A" is initiated.

(3) Auto closing of the valves occurs if any of the above permissives are lost.

c) Air ejector suction and discharge valves (valves 11 and 14 on Figure 2)

(1) Suction Opens if:

(a) SJAE "A" has a start signal,

(b) Condenser vacuum is $\geq$20" Hg vacuum, and

(c) The control switch for the valve is in open.

(2) Suction closes if any of the above signals are lost.

(3) Discharge Opens if:

(a) SJAE "A" has a start signal,

(b) Condenser vacuum is $\geq$20" Hg vacuum,

(c) Main steam pressure is $\geq$150 psig, and

(d) The control switch is in the open position.

(4) Discharge closes if any of the above signals are lost.

d) SJAE "A" Start Signal

(1) Signal "A"

(a) Off Gas Pressure <10 psig in one of two logic,

(b) Off Gas Temperature <165° twice, and

(c) HS-90-155 in Auto.

(2) Signal "B"

(a) Off Gas Pressure <10 psig is twice,

(b) Off Gas Temperature <165°F in one of two logic, and

(c) HS-90-155 in Auto.

(3) From the above logics it follows that any of the following combinations will terminate the start signal.

(a) Both pressure switches seeing ≥10 psig in the holdup volume.

(b) Both temperature switches seeing ≥165°F in the holdup volume.

(c) Either of the pressure switches seeing ≥10 psig with either temperatures switch seeing ≥165°F in the holdup volume.

e) Auto Start of SJAE "A" Initiate

(1) SJAE "A" Steam Inlet Control Switch in Auto,

(2) SJAE "A" Suction Valve in Open,

(3) SJAE "B" Steam Inlet Valve Opened.

(4) Condenser Vacuum ≤25" Hg. Vacuum, and

(5) SJAE has a Start Signal.

5. Off-Gas Preheater - (Two required one operating one standby)

   a. Location - Recombiner Room of Turbine Building

   b. Purpose

      1) Superheats steam-gas mixture exiting from the steam jet air ejector for efficient catalytic recombiner operation ($\sim$350°F).

         a) Alarm in control off gas temperature from preheater low set at 200°F.

      2) Ensures absence of water which poisons recombiner catalyst.

   c. Type

      1) U-tube heat exchangers 5.8 x 10^5 Btu/hour each

      2) Single pass carbon steel shell (Off-Gas)

         a) Shell design pressure 350 psig and temperature 400°F.

      3) Multi-pass stainless steel tubes (steam)

         a) Tube design pressure 1000 psig and 575°F

   d. Steam used for heating rather than electric to prevent explosion.

      1) Steam from main steam equalizing header through pressure regulator at   psig for normal operation.

      2) Steam from auxiliary boiler through pressure regulator at   psig for startup.

      3) Limits temperature to $\leq$400°F in event of loss of off-gas flow.

      4) Heating steam drains to main condenser.

6. Catalytic Recombiner (Two required one operating one standby)

   a. Location - Recombiner Room of Turbine Building

b. Purpose

1) Recombines hydrogen and oxygen gas into water vapor (superheated steam) at a variable temperature based on H_2 and O_2 (normally 800°F).

2) Must reduce hydrogen concentration to ≤1% by volume for conditions of low air flow. (Defined as one-third normal air flow.)

a) An intentional air bleed equal to low air flow is used when turbine condenser air in-leakage falls below minimum.

3) Catalyst causes mixture to burn slowly rather than explode.

a) Design heat transfer 2.2×10^6 Btu/hour/unit.

4) Freons, oil, halogens and water act as poisons to the catalyst.

5) Each recombiner has an external heating element to keep the spare unit at 350°F.

6) Alarms in control room catalyst temperature off normal.

a) High - 875°F

b) Low - 350°F

c. Construction

Stainless steel cartridge, low alloy steel shell. Catalyst cartridge containing a precious metal catalyst on nichrome strips or porous, nondusting ceramic. Catalyst cartridge to be replaceable without removing vessel. 350 psig design pressure. 900°F design temperature.

7. Off-Gas Condenser

a. Location - Recombiner Room of Turbine Building

b. Purpose - cools superheated steam and condenses water vapor. Effluent will be 130°F.

1) Rated 1.25×10^7 Btu/hour.

c. Type - U-Tube Heat Exchanger

1) Single Pass Shell (Steam and Air)

a) Design Pressure 350 psig

2) Multi-Pass Stainless Steel Tubes 600 ft.^{2} Surface Area (Condensate)

a) Design Pressure 250 psig

d. Cooling water from condenser hotwell downstream of gland seal condenser.

e. Drains to main condenser (gravity and vacuum)

f. Gas flow downstream of condenser consists mainly of air inleakage (18.5 SCFM) and noble gases.

1) Alarm off gas condenser gas outlet temperature high at 140°F.

2) Alarm gas flow off condenser discharge high 13.5 SCFM, low 4.0 SCFM.

8. Water Separator

a. Removes moisture entrained in off-gas condenser effluent.

b. Drains to off-gas condenser.

c. Carbon steel shell, stainless steel wire mesh.

d. Design conditions 350 psig and 250°F.

9. Dehumidifier Coil

a. Located in off gas pipe chase of turbine building.

10. 6 Hour Holdup Volume

a. Description - 54 inch pipe, 596 feet long, underground in proximity of ventilation stack.

b. Purpose

1) Reduce Activity Downstream.

2) Hold for decay of shorter half lived Xenons and Kryptons to particulate daughters. Allows particles to be removed by the prefilter rather than the charcoal.

a) $_{54}Xe^{138} \xrightarrow[14\ min.]{\beta^-} {}_{55}Cs^{138}$ (particulate) $\xrightarrow[32\ min.]{\beta^-} {}_{56}Ba^{138}$ (stable)

b) $_{36}Kr^{88} \xrightarrow[2.8\ hr.]{\beta} {}_{37}Rb^{88} \xrightarrow[18\ min.]{\beta} {}_{38}Sr^{88}$ (stable)
(particulate)

c. Actual holdup time will be approximately 6 hours with 18.5 SCFM air flow due to removal of radiolytic H_2 and O_2. This lowers the flow rate and increases holdup time from original 30 minutes to new value of 6 hours.

11. Cooler Condensers (Two required one operating one in standby)

a. Location

b. Purpose - Further cools gas-steam mixture for moisture control. Cools to 45°F. If the gas is saturated at 45°F., then at 74°F., the relative humidity will be 33% which implies that the moisture content of the gas is less than 1%.

1) Rated 1.1×10^5 Btu/hour each

c. Type - U-Tube Heat Exchanger

1) Single pass stainless steel shell (vapor and air)

a) Rated design pressure 350 psig

2) Multi-pass stainless steel tube (water and ethylene glycol)

a) Rated design pressure 100 psig

d. Charcoal efficiency is a function of moisture content (Figure 4)

e. Drains to equipment drains in Radwaste.

f. Design specification for system is <5% moisture.

12. Glycol Solution Storage and Pumping Equipment

a. Location

b. Purpose - Supplies cooling medium to cooler condenser.

c. Freon refrigeration unit cools glycol (temperature limits $33^{\circ}F$ - $36^{\circ}F$).

d. Components

1) Glycol Storage Tank

a) 3000 gallon carbon steel tank 7.5 feet in diameter 9.5 feet high

2) Glycol Pumps and Motor Drives (Two required)

a) 65 gal./min., 5 H.P. electrical

3) Glycol Tank Agitator and Motor Drive

a) Eliminates Thermal Gradients in Tank

b) 2 H.P.

4) Glycol Solution Refrigerators and Motor Drives (Two required)

a) $\sim 9 \times 10^4$ Btu/hr. each, single stage vapor compressor, 20 H.P.

b) Conventional refrigerator units w/chilling self-contained and pump exchangers, glycol exit solution temperature $35^{\circ}F$.

13. Moisture Separator (Two required one operating one standby)

a. Location

b. Purpose - Removes moisture from cooled gas exiting cooler condenser.

c. Construction - Carbon steel shell, stainless steel wire mesh, 350 psig design pressure, $150^{\circ}F$ design temperature.

14. Reheater

a. Location

b. Purpose - Heats gas to optimum temperature for charcoal ($77^{\circ}F$).

c. Construction - Carbon steel shell. 14 ft^2 surface area. 1,000 psig process pipe design pressure, 350 psig shell design pressure, $400^{\circ}F$ shell and tube design temperature.

15. Prefilter

a. Location - Filter Building

b. Purpose - Removes particulate daughter products (99.9% of 0.30 micron particles)

1) 160 cfm rating at 1" H_2O ΔP "clean" alarm in control room prefilter high ΔP, 10" H_2O ΔP

c. Construction - Carbon steel shell. High efficiency moisture resistant filter element, flanged shell, 350 psig design pressure, 150°F design temperature.

16. Charcoal Adsorbers

a. Location

b. Purpose - Delay Noble Gas (Xenon and Krypton) by Adsorption

c. Properties of Activated Charcoal:

1) High Adsorption for Krypton and Xenon

2) High Physical Stability

3) High Surface Area

4) Low Pressure Drop

5) High Ignition Temperature (>480°F)

6) Dust-Free Structure

d. Carbon adsorber vault maintained at 77° $\pm$ 2° by air conditioning units.

e. Bypass valve (valve 113B on Figure 2) used during initial startup and during periods of low activity operation. Will close automatically and the adsorber bed inlet valve (113A on Figure 2) will automatically open if either of the two carbon bed sample system radiation monitors sees a high, high high or high high high alarm.

f. Six charcoal beds with total weight of 18 tons. Vessels are 4 feet in diameter with an overall height of 21 feet, 16 feet of which is charcoal.

1) Design pressure 350 psig and design temperature 150°F

g. Krypton and Xenon Holdup Time

$$t_{holdup} = \frac{Kd\ M}{F}$$

Kd = dynamic adsorption coefficient (determined experimentally for each gas) - function of temperature, pressure and moisture content.

M = mass of charcoal (18 tons)

F = flow rate of gas and air (18.5 SCFM)

Xenon hold up time = 181 hours (design specification assuming K_{Xe} ~300) Expected to be >30 days.

Krypton holdup time = 15.7 hours (design specification assuming K_{Kr} - 18) Expected to be >40 hours.

h. Decontamination Factor (Table 1)

1) Definition - The activity leaving charcoal bed after some holdup time compared to before charcoal bed installed.

2) Very dependent on flow rate and fission gas distribution.

17. After-Filter

a. Location - under near stack

b. Filters radioactive fines and daughters products which escape from from charcoal.

c. Construction identical to prefilter

18. Off-Gas Isolation Valve (Valve 22 on Figure 2)

a. Isolates Off Gas Release to Stack

b. Air Operated Gate Valve

c. Normal open and close control on control room panel 8

c. Auto close if high radiation is detected by the carbon bed sample system.

1) Two Elements

a) Isolation Logic/Upscale High High High and One Downscale .

b) 2 Upscale High High High or

c) 2 Downscale

e. Auto Closes if SJAE Start Signal is Lost

19. Dilution Chamber and Fans

a. Dilution Chamber (1 Per Unit)

1) Purpose - provide a volume to mix fresh air provided by the stack dilution fans with off gas prior to stack discharge.

a) Dilutes in residual hydrogen prior to release precluding an explosive mixture in stack.

b. Dilution Fans

1) 2-100% capacity fans/unit

a) Standby pump auto start (if selected to auto) on trip of running pump.

2) Suction from fresh air discharge to dilution chamber.

20. Stack

a. Provides for greater dispersion of fission gases than a roof top discharge.

b. Main source of activity leaving stack is Xe^{133} with a $T_{1/2}$ of 5.3 days.

c. Major source of long lived activity is Kr^{85} (10.5 year half life) which contributes <20 μc/second.

d. 600 feet high

21. Condenser Hogging Vacuum Pump

a. Location - Just above SJAE room in turbine building near precooler.

b. Flow (rated) 3000 SCFM @ 15" Hg

c. Removes air from condenser shell and establishes sufficient vacuum for condenser operation at 20 to 25" of Hg.

d. Requires sealing water from pump to operate.

e. Discharges to stack via the gland seal holdup line.

f. Hogging pump can not be started unless:

1) Seal water pump is running,

2) Main steam line radiation is <3 x normal, and

3) Condenser vacuum is 27" Hg.

g. Hogging pump will auto trip if:

1) Condenser vacuum is ≥27" Hg, or

2) Main steam line rad. is ≥3 x normal, or

3) Seal water pump trips, or

4) Condenser vacuum is ≥22" Hg and Rx. Pressure is ≥600 psig.

h. Hogging pump suction valve will auto close if:

1) Main steam line rad. is ≥3 x normal, or

2) Condenser vacuum is ≥22" Hg and Rx Press ≥600 psig.

22. Gland Seal Condenser

a. Location - SJAE Room

b. Condenses turbine seal steam and removes non-condensables.

c. Single pass gland steam, double pass cooling water.

d. Discharge flow path

1) 2 Steam Packing Exhausters (SPE)

a) Normally maintain 10-12 inches of water vacuum on condenser by throttling discharge valve.

b) Standby unit auto starts if vacuum falls to 5" H_2O vacuum.

2) 1.75 minute holdup pipe

a) 24" pipe 1750 feet long

b) Allows decay of N^{16}, O^{19}.

3) Contributes .8 mR/year at site boundary.

F. INSTRUMENTATION AND CONTROLS

1. Off-Gas Pressure High (10 psig)

a. This is a 1-out-of-2-twice isolation logic which protects against an explosion in the holdup piping. It should be accompanied by a high temperature alarm if an explosion has occurred. Either trip channel will alarm.

b. The following valves should isolate: (valve numbers refer to Figure 2)

1) Off-Gas Isolation (28)

2) Filter Drain Valves (Not Shown)

3) Holdup Volume Drain (Not Shown)

4) Dehumidification Coil Drain (Not Shown)

5) SJAE Discharge Valve (14, 18)

6) SJAE Steam Isolation Valve (FCV 1-155, FCV 1-156 on Figure 3)

7) SJAE Drain Valve (Not Shown)

8) SJAE Air Inlet Valve (11, 15)

9) SJAE Steam Control Valve (PCV 1-151, PCV 1-1-153 on Figure 3)

2. Off Gas High Temperature (160°F)

a. Same as Off Gas Pressure High

3. Off Gas Pressure High 3.5 psig

a. This is a 1 out of 2 logic that prevents opening drain valves and establishes an alternate flow path for offgas flow when the off gas system is in use.

b. The following valves should isolate:

1) Dehumidification Coil Drain Valve

2) Filter Drain Valves

3) Holdup Volume Drain Valve

4. Main Steam Pressure Low 150^{0} psig

a. This is a one out of two logic which prevents attempted air ejector operation with out sufficient steam pressure.

b. The following valves should auto isolate:

1) SJAE Discharge Valve

2) SJAE Drain Valve

3) SJAE Air Operated Steam Admission Pressure Control Valves

a) Time delay around isolation for startup

5. Adsorber Off Gas Radiation High

a. Two radiation elements in off gas sample system

b. 4 Alarms

1) Hi Hi-Hi 1.13×10^{5} cps

2) Hi Hi 2.81×10^{4} cps

3) Hi 5.63×10^{3} cps

4) Downscale

c. Trips Off Gas Isolation Valve (28 on Figure 2)

1) Both Channels Hi Hi Hi or

2) One Channel Hi Hi Hi and the Other Channel Downscale or

3) Both Channels Downscale

d. Initiates charcoal adsorbers by opening adsorber inlet valve (113A Figure 2) and closing adsorber bypass valve (113B on Figure 2)

1) Any Channel Hi, Hi Hi or Hi Hi Hi

6. Condenser Vacuum Low ≤25" Hg Vacuum

a. Initiates Air Ejector Auto Start of Selected Standby Air Ejector

b. The following valves should respond:

1) The steam admission valves (motor and air operated) for the standby SJAE should open.

2) The motor operated steam admission valves for the running SJAE should shut.

7. Condenser Vacuum Low ≤20" Hg Vacuum

a. Ensures sufficient vacuum has been established prior to SJAE initiation.

b. Auto close the following valves:

1) SJAE Suction Valves (11 and 14 on Figure 2)

2) SJAE Discharge Valves (15 and 18 on Figure 2)

3) SJAE Drain Valves (Not Shown)

4) SJAE Steam Admission Valves (Motor and Air Operated)

8. Condenser Vacuum High ≥27" Hg Vacuum

a. Prevents operation of Condenser Vacuum Hogging pump when it is improper to dose.

b. Provides the following response:

1) Trips and interlock stripped the hogging pump.

9. Condenser Vacuum High (≥22" Hg Vacuum) with Reactor Pressure High (≥600 psig

a. Prevents operation of condenser vacuum hogging pump under these conditions and isolates hogging pump suction valve.

10. Hogging Pump Seal Water Pump

    a. Trips and interlocks tripped the hogging pump to prevent damage.

11. Main Steam Line Radiation Hi Hi

    a. Prevents hogging pump operation after fuel element failure by tripping the hogging pump and isolated it's suction valve.

12. Gland Seal Condenser Shell Side Vacuum Low $\leq 5"$ H_2O Vacuum

    a. Auto starts nonrunning steam packing exhauster

13. SJAE Condenser Condensate Pressure Low ≤ 60 psig

    a. Prevents operating SJAE with insufficient cooling water flow.

    b. Auto shuts SJAE air operated steam admission valves.

    c. Interlocks off of the SJAE condenser condensate inlet and outlet valves will do the same thing if either of them are closed.

14. Major Alarms.

    a. Off Gas Average Release Rate will be exceeded

        1) Indicates activity in the early portion of the holdup volume is >2500 mr/hr.

    b. Off Gas Radiation High

        1) Indicates activity in the early portion of the holdup volume is >5000 mr/hr.

    c. Stack Gas Radiation High

        1) Indicates activity high in stack gas sample $>3.8 \times 10^3$ cps

    d. Stack Gas Radiation High High

        1) Indicates activity high in stack gas sample $>7.6 \times 10^3$ cps

    e. Off Gas Hydrogen Analyzer High Alarm ($\geq 1\%$ H_2)

        1) Indicates recombiner failure and possible explosive mixture at the inlet of the holdup volume.

f. Off Gas Filter P High (10" H_2O at either operating prefilter or after filter)

1) Indicates need to switch filters

g. Preheater Discharge Temperature Low 200^oF

h. Recombiner Catalyst Temperature HIgh (875^oF/Low, 350^oF)

i. Off Gas Condenser Gas Discharge Temperature High 140^oF

j. Off. Gas Condenser Gas Flow High (13.55 cfm/low, 4.0 scfm)

k. Cooler Condenser Discharge Temperature High (48^oF/low, 42^oF)

l. Glycol Solution Temperature High (36^oF/low, 33^oF)

m. Gas Reheater Humidity High 48^oF Dew Point

n. Carbon Bed Temperature High 80^oF

o. Carbon Vault Temperature High 80^oF

G. SYSTEM FEATURES AND INTERRELATIONSHIPS

1. Gas Sources

a. Drywell Purge

b. Ventilation Systems

1) Radwaste

2) Turbine Building

3) Reactor Building

c. Gland Seal Steam

d. Mechanical Vacuum Pump

e. SJAE Discharge

1) Radiolytic Decomposition of Water

$$2H_2O \xrightleftharpoons[\gamma]{{}_0n^1} 2H_2 - O_2$$

2) Production Directly Proportional to Reactor Power.

a) .03 - .055 SCFM/$MW_{thermal}$

3) Air Inleakage to Condenser

a) 18.5 SCFM

4) Activation Gases

a) ${}_8O^{16} + {}_0n^1 \longrightarrow {}_7N^{16} + {}_1P^1$

$${}_7N^{16} \xrightarrow[7.4\ \text{sec.}]{\beta^-} {}_8O^{16} + \gamma$$

b) ${}_8O^{18} + {}_0n^1 \longrightarrow {}_8O^{19}$

$${}_8O^{19} \xrightarrow[29\ \text{sec.}]{\beta^-} {}_9F^{19} + \gamma$$

c) ${}_8O^{16} + {}_1P^1 \longrightarrow {}_7N^{13} + {}_2He^4$

$${}_7N^{13} \xrightarrow[10\ \text{min.}]{} {}_6C^{13} + \gamma$$

d) Important because they make the system a significant radiation hazard during operation.

5) Fission Products (Noble Gases)

a) ${}_{54}Xe^{135}$ $T_{1/2}$ 9 hours

b) ${}_{36}Kr^{88}$ $T_{1/2}$ 3 hours

c) ${}_{54}Xe^{138}$ $T_{1/2}$ 14.2 min.

d) ${}_{53}I^{131}$ (soluble in water) $T_{1/2}$ 8 days

e) ${}_{54}Xe^{133}$ $T_{1/2}$ 5.27 days (most prevalent source at stack)

2. Dilution of air ejector off-gas with steam to less than 4 percent hydrogen by volume to eliminate the explosion potential.

3. Recombination of radiolytic hydrogen and oxygen into water to reduce gas volume to be treated. Produces superheated steam.

4. Condensation of bulk water vapor.

5. Lag storage of the gas for 30 minutes to decay the bulk of the short-lived isotopes.

6. Further condensation of moisture from the gas to a 45^{O}F. dewpoint.

7. Reheating off gas to ambient temperature (74^{O})

8. Filtration of solid decay daughters from the off-gas.

9. Dynamic adsorption of Krypton and Xenon isotopes on activated carbon at 77^{O}F.

10. Final filtration of off-gas.

11. Monitoring of off-gas.

12. Disposal of decayed off-gas to atmosphere.

13. Returning condensate to process or the waste system for cleanup or recycle.

I. TECHNICAL SPECIFICATIONS

1. Release Limits

a. Intent: Keep as low as possible: in any event, within 10 CFR 20 limits.

b. Instantaneous Limits

1) Gross activity, other than I-131 and particulates with 8 day $T_{1/2}$:

$$\frac{Q_1}{0.13} + \frac{Q_2}{1.46} \leq 1$$

Where:

Q_1 = release rate from building exhaust fans in Ci secs.

Q_2 = release rate from main stack in Ci/secs.

a) Orderly reduction of power until within limits

2) I-131 and particulates with $T_{1/2}$ >8 days

$$\frac{Q_3}{.33} + \frac{Q_4}{44} \leq 1$$

where:

Q_3 = release from building exhaust vents in Ci/secs.

Q_4 = release rate from main stack in Ci/sec.

a) Orderly reduction of power until within limits

c. Average Limits

1) Gross Gaseous Activity

a) .10 Ci/sec. averaged over any calendar quarter

(1) Calendar quarter defined in 10 CFR 20.3 paragraph (4)

(a) ≥12 ≤14 consecutive weeks

(b) First quarter begins in January

(c) No day may be included in more than one calendar quarter or omitted from any calendar quarter.

b) .05 Ci/sec. averaged over any 48 hour period must be reported in writing to the Director, Directorate of Licensing in 10 days.

2) I-131 and particulates with $T_{1/2}$ >8 days

a) .8 Ci/sec. averaged over any calendar quarter

(1) See I.1.c.1).a).(1) above for calendar quarter definition.

b) .4 Ci/sec. averaged over a week must be reported in writing to the Director, Directorate of Licensing in 10 days.

c. Bases for Total Gas and I-131 and Particulates with $T_{1/2}$ >8 days.

1) 10 CFR Part 20 Appendix B Column 1 limits in unrestricted areas.

2) Constants determined by annual average site meteorology and an exposure dose of 500 mrem/year whole body.

3) I-131 and particulate with $T_{1/2}$ 8 days also include factor of 700.

4) Reason I-131 and 8 day particulate limit is gross is because 10 CFR Part 20 Appendix B, Table II, Note 2.c. apply's more severe limits to release of unknown mixtures than it does to know.

2. Monitoring Requirements

a. All radioactive gases released to the environment shall be monitored and recorded.

1) For effluent streams having continuous monitoring capability, the activity and flow rate shall be monitored and recorded to enable release rates of gross radioactivity to be determined on an hourly basis.

b. During release from stack, the following conditions must be met:

1) The gross β, γ activity monitor, the iodine sampler and particulate sampler shall be operating.

2) Isolation devices capable of limiting gaseous release rates from the main stack to within the values specified above shall be operating.

3) If, for an effluent release path there is no monitor operable, an equivalent monitor can be substituted to monitor this effluent release path or no effluents shall be released through that effluent release path until such monitor is made available.

a) A monitoring channel may be out of service for 4 hours for functional testing and calibration without providing a temporary monitor.

b) All waste gas monitors shall be calibrated at least quarterly by means of a known radioactive source. Each monitor shall have an instrument channel test at least monthly and a sensor check at least daily.

c) If the requirements for the stack gas monitor are not satisfied, the reactor shall be in Hot Shutdown in 24 hours.

4) At least one main stack monitor channel must be operating whenever any units SJAE, mechanical vacuum pump, or SBGT is in service.

5) Mechanical Vacuum Pump Isolation

a) The mechanical vacuum pump shall be capable of being automatically isolated and secured on a signal of high radioactivity in the steam lines whenever the main steam isolation valves are open.

b) At least once during each operating cycle verify automatic securing and isolation of the mechanical vacuum pump.

3. Sampling Requirements

a. Samples of offgas effluents shall be analyzed at least weekly to determine the identity and quantity of the principal radionuclides being released.